A TIME-GEOGRAPHIC APPROACH TO INVESTIGATING GENDER DIFFERENCE IN ACCESSING EMPLOYMENT OPPORTUNITIES IN A METROPOLITAN AREA

By

QINYUE PAN

Bachelor of Science in Geography
Suzhou University of Science and Technology
Suzhou, China
2006

Master of Science in Geography
East China Normal University
Shanghai, China
2009

Master of Science in Geography
University of Alabama
Tuscaloosa, AL
2011

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Dissertation Approved:

Dr. Hongbo Yu

Dissertation Adviser

Dr. Jonathan C. Comer

Dr. G. Allen Finchum II

Dr. John Kinder

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Name: QINYUE PAN

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Abstract: Gender inequality in employment remains an ongoing social issue in the United States. Although women's participation in the labor market has improved in the recent decades, the issue now is often manifested as occupational gender segregation, which is highlighted with women's overrepresentation in the service-oriented and lower-paying jobs. Taking a geographic perspective, numerous studies have focused on examining the statistical relationship between indicators of gender roles and commuting lengths to understand how traditional gender roles limit women's job accessibility. Nevertheless, the existing methods cannot explicitly explain the mechanism of how gender roles constrain women's time and lead to their disadvantageous status in accessing jobs. In addition, the spatial distribution of jobs, which also have significant influence on people's job accessibilities, cannot be fully incorporated in the commuting-based statistical analysis. Based on a time-geographic approach, this research proposes a new methodology framework to study the differences of men and women's space-time accessibilities to employment opportunities in a metropolitan area. It aims at offering an explicit explanation on how gender roles and job distribution patterns integrally function and impose different levels of space-time constraints on men and women's work activities, which leads to gendered accessibility patterns. Under the guidance of the proposed time-geographic methodology framework, simulated urban models, representing various job distribution patterns of monocentric and polycentric cities, are generated to help build knowledge on the connection between urban form and job accessibilities for men and women. In addition, the new methodology framework is also applied to a case study in Chicago Metropolitan Area, for the purpose of not only achieving further understanding on how the more irregular job distribution patterns in a real-world city will influence space-time accessibility to jobs, but also examining whether/how the gendered job accessibility patterns would contribute to the uneven distributions of men and women across occupations. The research is expected to provide useful insights on comprehending and assessing the situations of the occupational gender gap issues, and facilitate urban policy makers and planners to develop effective plans to improve gender employment equity in a city.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

Figure	Page

CHAPTER I

INTRODUCTION

1.1 Research Background

Equal employment opportunity between men and women has remained a heated topic for decades in the United States. Women's minority position in the U.S. workforce is constantly reflected by the gender differences in labor force participation and occupational distributions among workers. According to the Bureau of Labor Statistics (BLS), women comprised only one third of the total U.S labor force in 1950 (Toossi & Morisi, 2017). Although the past several decades have witnessed substantial improvements of women's participation in the labor market, demonstrated by a rising share of 45.8% in the 2018 labor market (BLS, 2018a) and expanded occupational choices including those once were exclusively dominated by men (BLS, 2012), occupational gender segregation remains a strong issue in today's society in the United States.

Occupational gender segregation usually refers to the unequal distribution of men and women into different occupations (Perales &Vidal, 2015). In the U.S. labor market, men are overrepresented in the executive and professional occupations, such as chief executive, computer and mathematical, architecture and engineering, and lawyer occupations, while female workers remain significantly overrepresented in the traditional female-dominated occupations, such as elementary and middle school teachers, healthcare support, personal care and service, and office and administrative support occupations (BLS, 2018b). Occupational gender segregation deserves concern from the policy makers, because it is closely related to women's lower wage level, which hurts the economic security of women and their families (Blau & Kahn, 2017). It also limits the optimal match of workers with jobs where they can fully contribute their skills, and eventually hinders companies from rapid productivity growth (Hsieh et.al. 2019).

The occupational gender segregation issue has received extensive attention among researchers. Various theories have been proposed to explain this problem from a socio-economic perspective. Neo-classic human capital theory attributes the underrepresentation of women in certain types of jobs to their lack of appropriate education and/or experience (namely human capital) for the jobs (Mincer & Polachek, 1974). Dividing the labor market into primary sector (which comprises high-paying and stable jobs) and secondary sector (which consists of jobs with lower salaries and less job stability), labor market segmentation theory focuses on the great resistance women face to move upward through sector because the primary sector "insulate[s] themselves somewhat from competition" (Anker, 1997, p. 322). Gender theory emphasizes the influence of the patriarchal norms on women's employment. Women are segregated into particular types of jobs highly due to the common stereotype of their skillsets (Eagly & Sczesny, 2009; Yoder, 2018). Approaching the problem from an aspatial perspective, these theories make valuable contributions to understanding the existence and persistence of gender occupational segregation from a social or economic angle and helping policy-makers develop plans to alleviate the problem. However, as employment can be considered as the outcome of a pairing process of job opportunities and matching employees at different places, space plays a natural and crucial role in understanding the employment patterns and characteristics in a city. Therefore, it is necessary to take a spatial angle when examining the occupational gender segregation in a society.

Geographers have taken a spatial approach to the gender employment disparity issues and focused on the factors that affect spatial accessibility to jobs. Numerous studies compared work-trip behavior between men and women. Repeated evidence demonstrated that female workers had shorter commutes than their male counterparts, regardless of whether commuting length was measured through physical distance or time (e.g. Kwan, 1999; McDonald, 1999; Crane, 2007; McLafferty & Preston, 2010). Through multivariate analysis, subsequent research (Johnston-Anumonwo, 1992; Turner & Niemier, 1997; Rapino & Cook, 2011; Fan, 2015) found that women's shorter commute could be significantly explained by variables representing their household responsibilities (such as parenthood, marital status and breadwinner status). The results indicated that the traditional gender roles left women less time for traveling to work than their male counterparts, which could further restrict women's job accessibilities. The commuting-based research contributes to revealing the association between women's gender roles and their commuting patterns. However, the statistical methods used in the studies cannot provide an explicit explanation on the mechanism of how different social roles lead to the difference in commuting distance. Besides, shorter commutes may not necessarily mean disadvantages in job accessibility. Commuting length is just one manifestation of the home-job matching process.

In addition to gender roles, previous research suggested that the spatial distribution of jobs also influenced men and women's accessibilities to jobs, which may have contributed to the uneven distribution of genders across occupations. Through in-depth interview, Hanson and Pratts (1992) found the labor market of firms in traditional female-dominated industries covered smaller fragments of the metropolis than those whose labor force were male-dominated. Wyly's (1998) research demonstrated that the high probability of women being in low-income, non-professional occupations could be explained by their short commute in a statistically significant manner. Both studies indicated a more dispersed distribution of the low-paying jobs, which provided women, whose commuting distances were restricted by their household responsibilities, easier access and hence led to their overrepresentation in these occupations. However, the methods employed by either study are unable to fully incorporate the spatial distribution of jobs in their accessibility investigation. Therefore, the studies have not revealed the differences of men and women's job accessibilities among locations in a city and the variations of job accessibility distributions among different occupations. The conventional place-based accessibility methods are able to capture the effect of job distribution patterns on accessibilities. However, the methods focus on places instead of individuals, hence cannot directly incorporate the varying time constraints faced by men and women when investigating accessibilities.

Therefore, a better understanding on the mechanism that causes the occupational gender segregation phenomenon in our society is needed. From a geographic perspective, this demands an effective research framework that can support an explicit investigation on how the conventional gender roles and the distribution patterns of home and employment jointly affect the employment opportunities accessible to men and women. Also, it is beneficial to have a research framework that can facilitate a comprehensive analysis on how men and women's accessibilities to job opportunities vary across a city, and how their accessibility distribution patterns differ from each other. Such a framework will provide useful insights on comprehending and assessing the situations of the occupational gender gap issues, and facilitate urban policy makers and planners to develop effective plans to improve gender employment equity in a city.

1.2 Research Objectives and Research Questions

This research will take a closer look at the gender difference in job accessibilities given their different space-time constraints in a metropolitan area to achieve a better understanding of the occupational gender segregation from a spatial perspective. The sources of the constraints will be based on the findings gained from the commuting-based studies: 1) time constraints, which are imposed by gender role constraints that limit women's available time for traveling longer distance to work; 2) spatial constraints, which are imposed by job distribution patterns that influence the available employment opportunities within individuals' reach given their time-budget constraint on work. Different from the conventional commuting-based studies which measure the constraints at an aggregate level, this research will take an individual-based approach and examine people's space-time constraints on employment opportunity accessibilities according to their daily activity patterns. A theoretical framework will be proposed to evaluate the access to employment opportunities within an integrated space-time system and examine how the different space-time constraints faced by male and female workers shape the gender difference in job accessibility.

The constraints in time and the space function inseparably to shape people's accessibility to job opportunities. While the conventional gender roles are based on societal norms and mainly belong to the field of sociology, the focus of this research would be rather on the spatial dimension of the constraints. As aforementioned, different types of occupations may demonstrate different spatial distribution patterns, which can form different compositions of available job opportunities for people living in different parts of the city. In addition, the urban form of a metropolitan area has a great influence on the distribution of employment locations and residential locations. Most occupations are expected to concentrate in the central city areas in a monocentric urban form, while in a polycentric form they tend to be more dispersed across the region or cluster around the subcenters. Individuals living in cities of different forms would experience different employment opportunities within reach given their constraints in space and time. Focusing on exploring the impacts of urban forms on employment opportunity equality between men and women, this research intends to tackle the following questions:

1) What are the differences between the daily activity patterns of men and women, in terms of the levels of space-time constraints for various types of activities? What activities impose constraints on men and women's employment activities respectively and how the temporal

spatial dimensions of these activities affect where and when men and women can access job opportunities?

2) How will the accessible employment opportunities vary for individuals living in different parts of a metropolitan area given their constraints in space and time? Which part of the city may have a better chance to support gender equality in accessing job opportunities? How will changes in urban forms influence the gender difference in employment accessibilities at different locations of the city? What type of urban form will promote a better chance of gender equity in accessing job opportunities?

3) How can we quantify the available employment opportunities to individuals? How can we compare the magnitude of employment accessibility between genders and among different locations in the metropolitan areas? How can we evaluate the impact of urban forms in terms of aggravating or alleviating gender inequity in employment accessibilities?

The time-geographic framework, originally proposed by Hägerstrand (1970) and his colleagues in Lund University, provides an efficient approach for studying and understanding individual's activity patterns in an integrated space-time context. The core concept of time geography lies in the idea that activities have both time and space components which cannot be separated in influencing an individual's activity patterns. Two constructs are defined in the time-geographic framework: space-time path and space-time prism. While a space-time path depicts the trajectory of an individual's movements in physical space over time (Yu, 2006), a space-time prism describes the space–time range that is physically accessible to an individual under a set of constraints (Miller, 2005). The space-time prism construct has been widely applied to analyze individual accessibilities in space and time (e.g. Kwan & Hong, 1998; Weber & Kwan, 2003; Yu & Shaw, 2008). However, there has not been research investigating the gender difference in employment accessibility using the time-geographic framework.

Therefore, a time geography based approach will be employed in this research to help better understand the employment accessibility for male and female workers and to answer the listed research questions. Different measures will be developed based on the space-time accessibility construct of time geography to evaluate men and women's accessible employment opportunities given their space-time constraints. A scenario-based analysis will be conducted in which the influence of urban form on gender difference in job accessibilities will be evaluated through the design of two sets of simulated cities. The implementation of the space-time accessibility measures will be demonstrated through a case study in Chicago Metropolitan Area (CMA) with the Travel Tracker Survey and the Census Transportation Planning Products (CTPP) data.

It is worth noting that although women on average shoulder more household responsibilities than men (Mannino & Deutsch 2007; England, 2010), the extent of such gender difference varies by marital status and family type (South & Spitze, 1994; Geist & Ruppanner, 2018). Previous research documented a high equity level of domestic labor division in same-sex couple (e.g. Patterson et al. 2004; Biblarz & Savci, 2010; Smart et al. 2017), and between single, non-cohabiting men and women, with or without children (e.g. South & Spitze, 1994; Hook & Chalasani, 2008; Barxter et al. 2010; Coles, 2015; Lee & Hofferth, 2017), mainly due to the reduced significance of gender played among partners of equivalent gender (Fulcher et al. 2008; Goldberg et al. 2012; Tornello et al. 2015), or the absence of the partners assumed to share housework with (Patterson et al. 2004; Geist & Ruppanner, 2018). The analysis of activity patterns and space-time accessibilities to jobs in this research probably does not apply to same-sex couples and single, non-cohabiting men and women which may not have great gender gap in time constraint on employment activities. Besides, household labor division and employment is also influenced by national context, including social policy (Geist, 2005; Hook, 2010), working time regime (Craig & Mullan, 2010) and cultural attitudes towards gender and family care (Knudsen & Warness, 2008; Lewis, 2009). The research is mainly based on the condition of the United States, and may not apply to the situations of other countries.

1.3 Research Significance

The proposed conceptual framework is expected to help understand the fundamental mechanisms behind the gender difference in access to employment opportunities in metropolitan areas. Since there is little research that has systematically analyzed the effects of urban forms on gender difference in job accessibilities, the results of this research are expected to shed light on identifying urban designs that can promote more equal access to employment opportunities between men and women. In particular, at the individual level, the findings would help dual-earner families to make better home location decisions so that the female workers can obtain more equal job opportunities with their male counterparts to work in occupations that receive higher earnings. At the city level, the results would help the policymakers improve the urban design to alleviate gender inequity issues in employment accessibilities.

CHAPTER II

LITERATURE REVIEW

Gender employment equity remains a challenging issue in our society. Its growing awareness among the public has inspired researchers from different fields to study the gender gap issues in employment. Taking a geographic perspective, geographers have been examining the spatial manifestation of gender employment disparity in an urban environment, and investigating various factors that may contribute to the disadvantageous status of women in the labor force. Traditional transport geography used commuting trip length as a proxy to reveal gender discrepancy in employment, and examined factors (e.g., socioeconomic characters, family structure, gender role, etc.) that may lead to women's shorter commute and limited accessibility to job opportunities (e.g.. Johnston-Anumonwo, 1992; Wyly, 1998; Fan, 2015). Taking an individual-based approach, time geography (Hägerstrand, 1970) offers an integrated space-time platform for studying people's activity patterns under various spatiotemporal constraints. This approach has been adopted in recent gender studies to examine how men and women's activity patterns are affected by different spatiotemporal factors. These studies demonstrate the potential of time geography as an effective framework for researchers to integrally deal with individuals' spatial and temporal constraints and understand how these constraints may lead to gender disparities in accessing employment opportunities. In addition, there have been extensive studies that explore the connections between urban forms and human activity patterns. As these studies examine how the variation of an activity's distribution across a city can affect people's accessibility to the activity and their travel behavior, they offer great insights on understanding the influence of job-housing distribution patterns on accessible employment opportunities. Therefore, this chapter provides a literature review in the following three areas: commuting-based gender employment studies, time geography and spatiotemporal accessibility analysis, and studies exploring the relationship between urban form and activity-travel behaviors.

2.1 Gender and Commuting Trips

Women's work trip patterns have gained increasing attention among researchers over the past several decades. Many studies (e.g. Johnston-Anumonwo, 1992; Wyly, 1998; Harley-Lock, Bermand & Timberlake, 2013; Fan, 2015) examined female workers' commuting lengths and consistently found that women had shorter journeys to work in comparison to their male counterparts. Attempting to explain why women had shorter commutes, researchers proposed and tested various hypotheses. These hypotheses generally fall into two categories. The first is known as the household responsibility hypothesis, which mainly focus on women's traditional gender roles that impose time constraints on women's commuting trips. The second adds the spatial distribution of housing and job locations as another factor to explore women's more limited accessibilities to jobs and their disadvantaged status in the labor market, which is often termed as "spatial entrapment hypothesis". They provide different aspects to understanding women's shorter commute and gender inequity in occupations.

2.1.1. Women's shorter commute and household responsibilities

A number of studies compared the commuting trips between men and women since the 1960s. Most research conducted before this time merely focused on the commuting behaviors of the "heads of the households" (Morgan, 1967; Ericksen, 1977), who were usually male in the family.

However, with the dramatic increase in the size of female labor force in the United States, researchers began paying attention to the characteristics of women's journey to work. Given women's significantly different experience at home and workforce from men's, researchers believed that the commuting patterns of female workers would also differ from men's.

Many studies discovered that the commuting trips between men and women varied in many ways, such as commuting length, travel mode, and frequency of trip chaining (Mauch & Taylor, 1997; Schwanen & Ettema, 2016; Gossen & Purvis, 2004; McDonald, 1999; Weinberger, 2007; Crane & Takahashi, 2009; Goddard, Handy & Mokhtarian, 2006; Preston & McLafferty, 2016; McLafferty & Preston, 2019; Fanning Madden, 2016). Among these differences, women's shorter commute has been studied the most. Consistent findings showed that female workers tended to have shorter commutes than male workers, no matter if it was measured in time or physical distance. For example, with 1985, 1995 and 2005 American Housing Survey, Crane and Takahashi (2009) suggested that women's commuting time was between 8.1% and 14.4% shorter than men's from 1985 to 2005. The research also indicated that the gender gap in commuting length was even wider if measured by miles, which ranged from 24% to 37%. Gossen and Purvis (2004) found a 10 minute difference in the journey-to-work length between male and female workers with the 1990 Bay Area Travel Surveys in the San Francisco Bay Area. Harley-Lock, Berman and Timberlake (2013) indicated a 10 minutes gender disparity in commuting length with the 2008 National Study of the Changing Workforce data.

Why would there be a persistent gender gap in the length of work trips? Numerous researchers focused on explaining the reasons behind women's shorter commute. The main approach was based on the hypothesis that female workers tended to shoulder heavier household responsibilities due to traditional gender roles, which left them less time for traveling to work than their male counterparts. To test the hypothesis, multivariate analysis was utilized to explore the statistical relationship between men and women's average commuting length and their household responsibilities and socio-economic status, such as income, travel mode, residential location, occupation type and household structures. Most studies indicated that the household structure related variables, such as marital status and presence of children, had a significant effect on the gender difference in commuting. These results were interpreted as traditional gender roles which constrained women's time for traveling to work. As assumed by the common societal norms, women (especially married women with children) were the primary household caregiver (Fanning Madden, 2016). In most families, the housewives tended to shoulder more household responsibilities than their husbands. Since most household tasks occupied a large amount of time, women tended to have a more limited time budget for work. Therefore, women were more likely than men to choose jobs that were close to their home locations so that they could fulfill both their work and gender roles and to keep a work-life balance (Harley-Lock, Berman, & Timberlake, 2013).

Johnston-Anumonwo (1992) compared the gender gap in commuting distance between single-worker households and couple-worker households using t-test with the 1977 Travel Demand dataset for Baltimore Metropolitan Statistical Area (MSA). It was with the hypothesis that 1) male and female workers in single-worker households would shoulder similar levels of household responsibilities and thus had similar commuting length; and 2) the gender difference would be much larger in double-worker households due to the probably imbalanced domestic labor division between male and female members. The results supported the author's hypothesis that women from single-worker households had similar commuting distance with their male counterparts, while women from two-worker households had significantly shorter commuting distance than their husbands did. Other socioeconomic variables, including income, travel mode, living in the city vs. suburb, occupation type and child status, were controlled when conducting the analysis. Since the results indicated that men in the couple-worker households remained travel longer than their women counterparts after the child status variable was controlled, it may have also suggested that parenthood was not an important factor leading to women's shorter commute.

Turner and Niemeier (1997) employed the 1990 Nationwide Personal Transportation Survey data to investigate the effect of marital status and parenthood on commuting distance and time for employed men and women through reduced form equation method. The results illustrated that marriage status negatively influenced women's commuting time, which supports Johnston-Anumonwo (1992)'s findings. However, different from the conclusion of Johnston-Anumonwo (1992)'s study, this research suggested that the presence of children within the household reduced both women's commuting distance and time.

Fan (2015) also examined the factors that contribute to the gender gap in work trips through log-linear regression analysis and chow test analysis with 2003-2010 American Time Use Survey data. The results supported the hypothesis that women's household responsibility increased the gender gap in commuting length. Nevertheless, different from the studies reviewed above, Fan's (2015) study suggested that the effect of two household responsibility indicators, marriage status and the presence of children on women's shorter commute was conditional. According to the study, the presence of spouse/partner increased the gender gap in commuting, but only among households with children. When the parenthood variable was controlled, the presence of spouse/partner itself did not have a significant effect on commuting. Similarly, the presence of children was also found to significantly increase the gender difference in commuting, but only when both parents were the breadwinners.

Rapino and Cooke (2011) utilized the 5% Public Use Microdata Sample of the 2000 U.S. Census to evaluate the influence of gender roles on women's commuting. In addition to variables that represented household responsibilities (including marriage status and parenthood), their study introduced same-sex male and female couples as a control group into the methodology framework. The hypothesis was that the labor division within the same-sex households would be more balanced than within the heterosexual households, and hence the difference in commuting length between the same-sex partners would be much smaller if traditional gender roles are the key factor in decreasing women's commuting length. The results of the study supported the hypothesis. As demonstrated by the results, married women had significantly shorter travel time from home to work than married men. However, the commuting time of the female workers from same-sex households had no significant difference from that of the male workers from the same-sex households. Besides, the female workers in the same-sex households also had very similar commuting time with that of married men. The results indicated that the traditional gender role was the major source of constraint on women which limited their work trip length. When the domestic labor division became more equal between the spouses/partners, the constraint was greatly relieved and the gender gap in commuting would be considerably reduced.

Although there are mixed and inconclusive findings on what detailed aspects of the family (mainly due to the data and methods the research adopted) have contributed to women's limited time for traveling to work, the research illustrates how women's traditional gender roles restrict their capability of traveling to work. However, while the quantitative methods reveal the association between women's gender roles and their commuting patterns, they do not provide an explicit explanation of the mechanism of how different gender roles constrain individuals' commuting distance. Besides, another limitation is that shorter commutes may not necessarily mean disadvantages in job accessibility. Commuting length is just one manifestation of the home-job matching process. Finally, while this group research illustrates women's more restricted mobility on commuting, it has not explained why men and women would segregate in different occupations.

2.1.2 Spatial entrapment hypothesis

While the studies described above primarily focused on the effect of traditional gender roles on women's job accessibility, the spatial entrapment hypothesis introduced the spatial distribution of jobs into the discussion. This group of research suggested a job distribution variation among occupations, which might have been a factor leading women to be entrapped in traditional female-dominated occupations.

The most famous study contributing to the spatial entrapment hypothesis was conducted by Hanson and Pratt (1992) who studied the process of the spatial segmentation of the local labor market using in-depth interviews with employers and employees in firms in manufacturing and production service industries in Worcester, Massachusetts. The research suggested that the labor market was spatially segmented within the metropolitan areas. Workers and firms together played an essential role in shaping the localized labor market through interdependent actions with each other. On the one hand, the employers had good knowledge about the distribution of labor force in terms of their skill, cost and geographical mobility, and developed various place-based strategies to tap the labor they desire. The employees, on the other hand, preferred jobs that were closer to their residential location and relied highly on localized social networks in the job-search process. As a result, the extremely localized labor market was created, with each area having its own occupational and labor force characteristics. As indicated by the research, the male-dominated labor market segment had significant differences with the female-dominated market. Among the interviewed firms, the textile and yarn firms, whose labor force were mainly female (around 70%), had labor market areas that were closely around the firms' sites and covered smaller fragments of the metropolis than that of the high-technology firms whose labor force were male-dominated (70%-80% male workers). The difference was mainly due to women's heavier household responsibilities so that they were more likely to consciously minimize their work trips than men. The firms in traditionally female-dominated industries understood women's more restricted job search orbits than men and hence tended to locate/relocate their firms to attract a female labor force. In this way, a gendered spatial segmentation of the labor market was established over time, which then increased the likelihood of women to be entrapped in traditionally female-dominated jobs.

Wyly (1998) also obtained evidence that supports the spatial entrapment theory when examining the validity of two views regarding the relationship between occupational gender segregation and women's shorter commute. The first view states that women's concentration in particular types of jobs is the outcome of the process of matching jobs with workers based on their aspatial characteristics. Although women have significantly shorter commutes than men, it is considered as merely the incidental spatial outcome of gendered occupational segregation: women are concentrated in female-dominated occupations, and female-dominated jobs are more dispersedly distributed than male-dominated ones, therefore women have shorter commutes than men. The second view supports the spatial entrapment hypothesis that women's shorter commute indicates women's gender role constraint on traveling, and the gender role constraint as well as the spatial distribution of gender-segmented jobs reinforce women's concentration in female-dominated jobs.

Regression models were established to test the validity of the two views with 1990 one percent national PUMS data. In the regression for evaluating the first view, commuting lengths were represented as a function of the occupation types and other socio-economic factors with the assumption that commuting could be predicted by occupation types if women's shorter commute is the spatial outcome of occupational gender segregation. In order to examine the second view, two regression models were established. One modeled women's commute length as a function of the household responsibilities and other socio-economic variables, examining the influence of gender roles on women's work-trip mobility. The other modeled the probability of women being in female-dominated occupations as a function of the commuting length of female workers, which investigated whether female-dominated occupations tended to be closer to residential locations. Besides, the two models together also explored whether the traditional gender roles led to women's concentration in female-dominated occupations, if linking the common part of commuting length in both models. The results of this regression provided no support for the former hypothesis but demonstrated that women's concentration in female-dominated occupations was significantly explained by women's shorter commute.

Through different methods, the above two studies have revealed the roles played by space in influencing men and women's employment. However, the time-budget constraint and the spatial distribution patterns of jobs determine individuals' accessible employment opportunities in an integrated way, which cannot be fully and efficiently expressed by the methods. The decrease (or increase) of time budget will not directly lead to the decrease (or increase) of individual's accessible opportunities without examining the change of distribution patterns of home and jobs, and vice versa. As a result, the different distribution patterns of job accessibilities between men and women cannot be illustrated through the methods. Therefore, an alternative methodology framework is necessary to support an explicit investigation on the mechanism on how the conventional gender roles and the distribution patterns of home and employment will jointly affect the employment opportunities accessible to men and women. It can provide a platform to better evaluate and compare the gender difference in employment opportunities.

2.2 Time-geographic Framework and Space-time Accessibility Measures

The commuting-based studies illustrate women's higher level of spatio-temporal constraints than men, which has restrict women's accessibilities to jobs. However, the methods used by the studies have not explained the mechanism on how the time and spatial factors interactively function and affect women's job accessibilities. Serving as the conceptual methodology basis of this dissertation, the time-geographic framework is a constraint-oriented framework and provides an effective and efficient platform for investigating human activity patterns. Different from the conventional statistical analysis that predicts human behavior based on their socio-demographic attributes, time geography aims at analyzing various types of constraints individuals face and how these constraints restrict their freedom to move around and participate in activities. The following subsection will introduce the time-geographic framework, including the basic concepts and approaches, the applications of time geography on studying individuals' travel-activity patterns, and the connection of this dissertation with the studies.

2.2.1 Time geography and constraints

Time-geographic framework was first proposed by Hägerstrand (1970) as an approach to better understanding human activity patterns. Rather than examining people's behaviors in an aggregated form, it mainly focuses on individuals' daily experiences through time and space. Instead of investigating individuals' freedom to move around, time geography pays attention to how various constraints in their daily lives limit their opportunities to reach certain places at certain times (Weber, 2003). Time geography provides an integrated space-time framework to study the relationship between the constraints and individual daily activities. In particular, three types of space-time constraints are defined, termed as capability constraints, coupling constraints, and authority constraints.

Capability constraints refer to the limitations that are caused by the biophysical construct of human beings and/ or the limitations of tools in moving among activities that are located in different places (Hägerstrand, 1970). For example, sleeping and eating are the two activities that are with high regularities in their timings and durations for every individual human being. They tend to have high level of constraints on individuals' daily lives, dividing individual daily time windows into discontinuous sections and drawing time boundaries for the remainder of daily activities. In addition, transportation tools also impose constraints on individual daily activity patterns. Activities are usually located at different places. People need to travel to move from one activity location to the next, in order to take part in certain activity. Travel takes time, however. Since time is not infinite, the more time the individuals spend on travel, the less they have for activities (Yu, 2006). Improving transport technology would reduce travel time and thus leave more time for conducting various activities. For example, the invention of flight largely releases individuals' constraints and allows individuals to participate in activities located thousands of miles away from each other.

Coupling constraints are caused by the necessities to accomplish tasks with others. Individuals participating in the same tasks are usually required to stay at the same places during the same period of time to cooperate with each other. The locations and/or time of the tasks are hard to alter once they are anchored. Therefore, the freedom of the participants to move around during the anchored time is constrained. Most employment activities are the typical types of activities that impose coupling constraints on individuals' daily lives. Workers go to certain locations to work with others at certain time for certain hours, during which the workers have little freedom to move around and participate in other activities. Besides, many types of household tasks can also be considered as the source of coupling constraint. For example, when individuals are responsible for taking care of family members, their time and space are highly bounded with the time and space of the people they are taking care of. In this case, the freedom of the care givers to participate in other activities are constrained. Another example would be food preparation and related cleaning activities. Although these activities do not require the participation of the other individuals, the need to work with the tools (e.g. cookware and cooker) which are installed at home for a certain time duration also binds the individuals to a confined space and time and constraints their freedom to moving around.

Authority constraints are imposed by the rules and regulations of the society, which determine whether an individual can conduct certain activities at specific time and locations. For example, a person's freedom of driving will be constrained if s/he does not have a driver's license. Besides, the local governments, libraries, post offices and shopping malls have certain opening hours. The necessities for individuals to be at the locations of the facilities during the opening hours will influence the participation of individuals in other activities.

The system of constraints illustrates the barriers in space and time that individuals have to overcome to accomplish tasks, and hence defines the individual daily activities patterns regarding when and where, for how long and with whom the activities will be. These three types of constraints apply to everyone. However, the types and levels of constraints experienced by individuals can vary significantly. Being the primary family care giver and housework conductors, women tend to carry out more household-related activities. As aforementioned, many household related activities impose stringent space-time constraints on individuals. In this case, women usually bear higher level of constraints due to their gender roles. They restrict women's options to traveling and/or participating in other activities. While the commuting-based studies predict employment accessibilities or travel behaviors based on individuals' attributes, time geography explains the mechanism of why women have more limited choices than men in employment activities.

2.2.2 Space-time paths and space-time prisms

Two powerful tools are developed to help visualize and analyze individual activity patterns within the integrated space-time context: the space-time path and space-time prism. A space-time path is the trajectory of an individual's movements in physical space over time (Yu, 2006). It provides a representation of an individual's activities, including the starting/ending time and location of an activity, and the sequence of activities. Figure 2.1 demonstrates how the space-time paths can depict an individual's movement in space and time. The individual in the example starts his/her activities at 7:30 in the morning at location A, and then he/she stays at B until 12:00 and then spends 10 minutes to travel from B to C. After 40 minutes staying at C, he/she travels back to B and stays there until 17:00. The individual then spends 30 minutes to go back from B to A. As illustrated in the above example, both the spatial and temporal characteristics of an individual's movements are integrated under the concept of a space-time path (Miller, 2005). The tilted line segment (A, B) represents the individual's movement over time from location A to B, and the vertical line segment represents his/her stationary at the activity location C for a certain duration of time. The smoother the slope between the tilted line segment and the horizontal line, the faster speed the individual is moving. Besides, the longer the vertical line segment, the more time the individual stays for the activity.

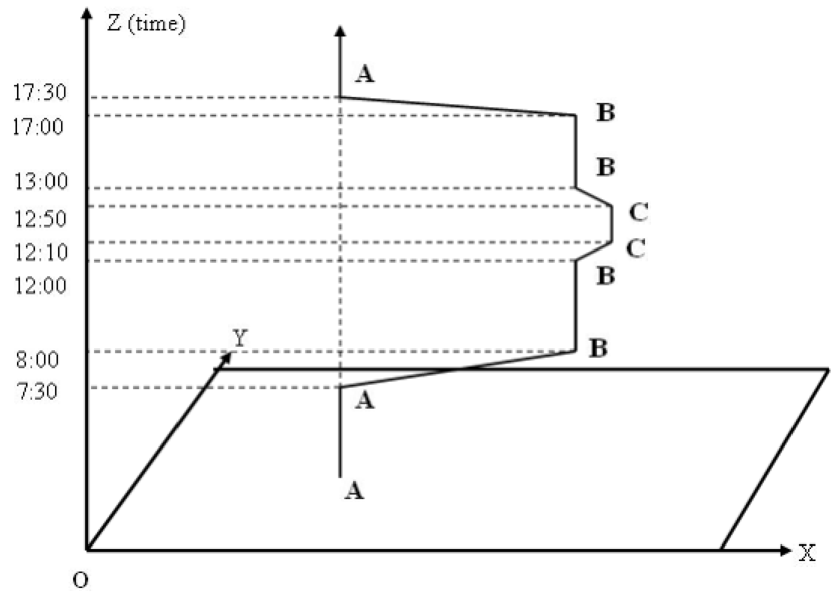


Figure 2.1. The concept of space-time paths

The space-time prism describes the space–time range that is physically accessible to an individual under a set of constraints (Lenntorp, 1976). While the space-time path mainly focuses on the actual movement of individual, the space-time prism is usually adopted to depict the area for potential actions of the individual given his/her time constraint in space and time. Figure 2.2 represents the concept of the space-time prism. As shown in the figure, there are two 3D points O and D, denoted as O(x_o, y_o, t_o) and D(x_d, y_d, t_d), which represents locations of two already anchored activities of an individual in his/her schedule that they already know will occur. This individual won't leave location (x_o, y_o) until t_o and will need to reach location (x_d,y_d) before t_d. In this case, the freedom of s/he to moving around is constrained. The space-time prism is used to delimit the space-time extent available to the individual under the constraint of O and D.

As demonstrated by Figure 2.2, the prism is composed of two cones: a time-forward cone which starts from location O and moves upward, as well as a time-backward cone which ends at location D and moves downward. The time-forward cone delimits the extent of all locations in space and time that can be reached within a certain time period from the origin at a given speed, while the time-backward cone demarcates the extent of all locations in space and time that an individual can depart from and reach location D within a certain time period. The volume of the space-time prism is mainly associated with two factors: 1) the location and time of O and D; and 2) the travel speed of the individual. The times of the two anchor points define the total time budget the individual has to move around, while the locations of the two anchor points determine how much time the individual need to travel from origin to destination, and hence how much time is left for the individual to participate in other activities. The speed determines how fast the individual can trade time for space. The higher the speed, the larger space the individual can reach under the limited time budget.

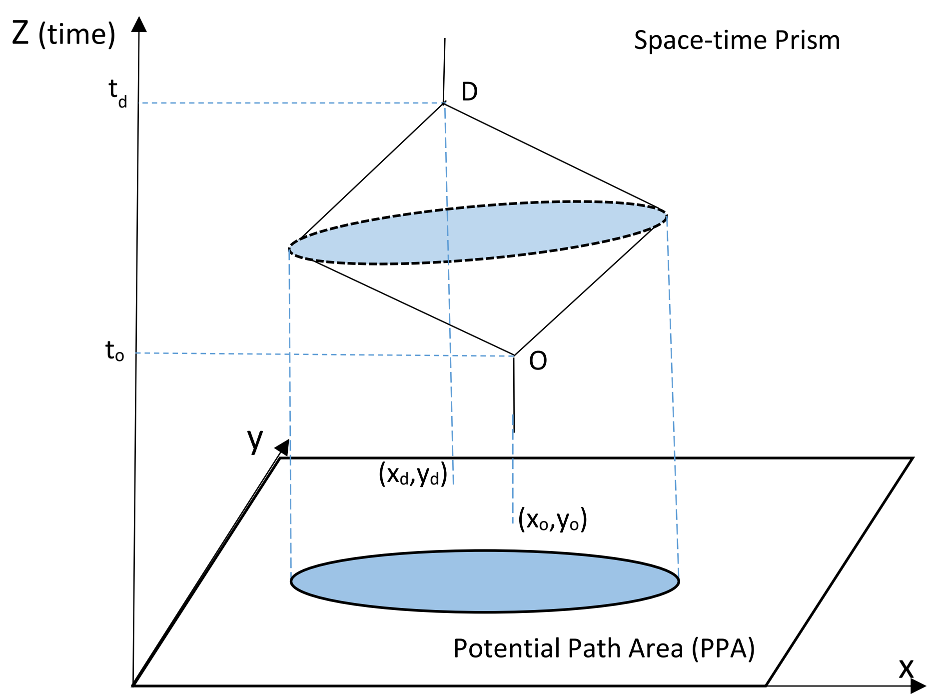


Figure 2.2. The concept of space-time prisms

The projection of the 3D space-time prism on the 2D geographical planar space is called the potential path area (PPA). It delimits the extent of the geographical space that can be reached under the space-time constraints of the two anchor points. Opportunities that are located within the boundary of the PPA compose the opportunity set that the individual can access given the constraints of O and D.

The space-time prism is provided as an efficient tool for evaluating individuals' space-time accessibilities given the amount of time available to him/her as well as the ability to travel among different locations. Whether an activity at certain time and location is accessible to an individual can be evaluated by whether the activity (represented by a vertical line segment in the space-time system) is completed within the boundary of his/her space-time prism. Besides, the concept of space-time prisms involves space, time, transportation, and land-use configuration simultaneously, which make it capable of examining various patterns regarding individual activities, interactions among individuals and the interactions between human and the land use and transportation systems (Song & Miller, 2014). The space-time prism has been widely applied by geographers to analyze individual accessibilities in space and time. For example, Kwan and Hong (1998) investigated the spatial choice set for discretionary activities based on the concept of space-time prism using travel diary data collected in Columbus, Ohio. The spatial choice set, named by the author as the cognitive feasible opportunity set, contained the spatial alternatives of discretionary activities within reach given individual's space-time constraints while were also located in areas that were familiar to the individuals. Weber and Kwan (2002) improved the space-time accessibility measures by incorporating the effects of traffic condition and facility opening hours. The results of the case study in Portland, Oregon demonstrate the ability of the improved measure for a more accurate reflection of individual accessibility within the cities. The findings also reveal the complexity of the relationship between individual activities and the urban environment when the time dimension was taken into consider. Shaw and Yu (2009) extended the time-geographic framework for exploring potential individual activities in both the physical and virtual spaces. The adjusted space-time accessibility measure developed in the study allows for the identification of the information regarding when and where (in physical space) the individual can access the virtual space, as well as the opportunities for potential interactions among individuals in a hybrid physical-virtual space.

In the conventional commuting-based analysis, commuting-length was used as a proxy for measuring men and women's accessibility to jobs. As the outcome of work-job matching process, commuting length can be influenced by multiple factors and hence cannot accurately reflect the difference in accessibility between men and women given their different spatio-temporal constraints. This research will use the space-time prism construct to help evaluate gender gap in accessing jobs. In such a way, the individual's accessibility to jobs will be identified as the collection of opportunities that fall in the space-time extent delimited by the space-time prism given his/her space-time constraints. Compared with the conventional commuting-based measures, the space-time accessibility measure will facilitate a more accurate analysis of the disparities between men and women's accessibility to employment opportunities given their different space-time constraints.

2.2.3 The application of time-geographic framework on gender studies

There has been limited research that analyzed gender difference in accessing jobs with the time-geographic framework. Kwan (2000a) examined the gender difference in the level of daily space-time constraints in Franklin County, Ohio. A travel diary survey was conducted in the research. A group of respondents, including full-time employed men, full-time employed women and part-time employed women in the study area were selected to participate in the survey. Besides providing information regarding the time, location, purpose and travel mode of each of their activities conducted on the survey day, the respondents were also asked to specify if it was difficult to change the place and/or time of each activity. Activities were then defined as flexible or fixed in space and/ or time according to the answers to the questions: an activity was labeled as fixed in space/time if it was hard to change its location/time; otherwise, it was labeled as flexible. Through a summarization of the survey results, the author found that both the number and composition of the type of the fixed activities conducted by women were almost twice as many as those by men regardless of their working status. According to the results, work and work-related activities were the major source of the respondents' daily fixity constraints (imposed by out-of-home activities of which the time and space are fixed). This was especially true for full-time workers, whose work activities occupied long period of time daily and the location of the activities were mostly fixed. Among full-time workers who shared similar work constraints, female workers encountered higher level of daily constraint than male workers. Moreover, part-time employed women, who did not have as much work constraint as the full-time workers did, faced even higher level of fixity constraints than full-time employed men and women. This was due to women's gender roles, which had functioned as a very important source that limited women's daily activity flexibility.

Based on the information regarding the fixity level of activities collected from the survey in Kwan (2000a), Kwan (2000b) compared the individual space-time accessibility between full-time employed men and women through a time-geographic approach. The daily potential path areas (DPPA) for 28 full-time employed men and 27 full-employed women were constructed and the number of opportunities, the length of road segments and the average area of parcels contained in the DPPA for each individual were calculated as indicators of the individual's accessibility. The results suggested a significant difference in individual space-time accessibility between the male and female subsamples. According to the results, both the area of the DPPA as well as the number of opportunities in the DPPA of women were significantly smaller than that of men: the average number of women's urban opportunities contained in the DPPAs was 44% less, while the average area of their DPPAs was 64% smaller than that of men's. However, the composition of opportunities contained in women's DPPAs was similar with that of men's and the density of opportunities in women's DPPA's was even higher. The findings indicated that although women were constrained in significantly smaller potential activity space by more number of fixity activities, they tended to conduct their daily activities in area with denser opportunities as an "adaptive strategies" to compensate the disadvantages of their smaller activity area. Besides, the difference in the size of parcels in the DPPAS between men and women was not statistically significant, meaning that the spatial tendency of the DPPAs for men and women was similar.

These studies demonstrate the effectiveness of understanding the gender gap in daily accessibility patterns from the perspective of different level of constraints between genders. However, they mainly focuses on the accessibility of non-employment activities, while employment activities are considered as fixed in time and space that anchored the action space for male and female workers. Therefore, how the access to employment opportunities differs by gender remained unclear in the studies. The measure of the DPPA illustrates the feasibility of examining the individual accessibility in combination of the land-use characteristics. However, since the size of the subsample used in the empirical study is comparatively small and spatial distribution of their home locations is unclear, it is difficult to make inference about whether and how the urban form influences the gender difference in their space-time accessibilities.

2.3 Urban Form and Activity-travel Patterns

The commuting-based gender studies revealed the uneven spatial distribution of jobs and housing locations as one of the major constraints that reduce women's accessibility to employment opportunities. However, limited effort has been dedicated to explicitly examining the impact of the spatial arrangement of jobs on gender differences in accessing jobs. Questions such as how the job/house distribution patterns will influence men and women's job accessibility differently and how the gender gap in job accessibility varies across the city remain unanswered. In the meantime, there has been extensive research examining the influence of spatial distribution of jobs and housing locations on employment-related activity travel behaviors in general. They are usually under the rubric of urban form studies. In particular, most studies focus on the changes in American cities over the past decades and how such changes will alter the commuting patterns and job accessibilities of urban residents. The following subsection will take a brief review on this body of research, upon which a better understanding on the complexity of the spatial organization of jobs and houses as well as its relationship with people's employment can be obtained.

2.3.1 The concept and types of urban form

Urban form is defined as the distribution of various urban opportunities as well as the interaction between people, goods and information flow among those opportunities (Ibrahim, 1997). It can be related to almost everything within the urban area, such as government, school, hospital, street, people and so on (e.g. Pitombo, Kawamoto & Sousa, 2011; Harding et.al. 2012; Brown, Khattak, & Rodriguez, 2008). Within the scope of jobs and housing locations and its impact on employment activities, urban form is usually referred to as the spatial arrangement of housing and employment opportunities (e.g. Modarres, 2011; McMillen, 2001; Redfearn, 2007; Sultana & Weber, 2007; Horner, 2006; Scott & Horner, 2008). Based on this narrower term, urban form can be divided into majorly two types: the monocentric urban form and the polycentric urban form.

The theoretical model of the monocentric urban form can be traced back to Von Thünen's (1966) land use model for agricultural landscape. It describes a concentric state with a market located at the center of the state along with various agricultural commodities competing for the rings closest to the central market for lower transportation costs (Arribas-Bel & Sanz-Gracia, 2014). Alonso (1964), Mills (1972), Muth (1969), and Wheaton (1974) then refined the model, replacing the agricultural land-use with the land-use of urban industry, business and residence. In a standard monocentric model, there is only one economic center, which is referred to as the Central Business District (CBD). All employment opportunities are distributed in the CBD and all workers commute from the outside to the CBD for work. The housing price decreases as the location becomes more distant to the CBD. In reality, although it is impossible that no jobs are distributed outside the CBD area, the CBD should hold the largest proportion of employment opportunities in the city. With population growth and innovation in transportation technology, metropolitan areas have experienced a large degree of decentralization. On the one hand, the proportion of jobs in the traditional CBDs become much smaller. On the other hand, new employment centers are formed outside the central cities with large concentrations of jobs that are comparable to the CBD area. The new employment centers are referred to as the 'employment subcenters' and the new urban form with one traditional CBD area and multiple employment subcenters is termed as the polycentric urban form.

The empirical identification of urban form has received widespread attention. Many studies have been dedicated to developing a better equation to more accurately model the employment density surface, and to better identify the employment centers of an urban region. The various equations proposed by the research have been applied to a variety of urban regions in the United States. The results provide useful information for better understanding the overall development of the spatial distribution patterns of employment of U.S cities. Among the research, most has focused on evaluating the urban form of the largest metropolitan areas, such as Chicago (McMillen & McDonald, 1998; McMillen, 2001), Los Angeles (McMillen, 2001; Lee, 2007; Redfearn, 2007), San Francisco (McMillen, 2001; Lee, 2007), Dallas and Houston (McMillen, 2001). Almost all the results demonstrated strong polycentric characteristics of these regions, which led to a consideration that polycentricity had been the predominant form in the United States. Based on the above research, one might have a doubt on whether the monocentric form is still applied to American cities. However, two recent studies (Arribas-Bel & Sanz-Gracia, 2014; Hajrasouliha & Hamidi, 2016), which took an overall evaluation on the urban form of most of the metropolitan areas in the United States, shed light on understanding the validity of monocentric form of the country.

Arribas-Bel and Sanz-Gracia (2014) examined the urban form of 359 metropolitan areas in the US in three different years: 1990, 2000 and 2010. To detect clusters of neighborhoods (at census tract level) with high employment density, local spatial autocorrelation method was adopted, which included Anselin's LISA for identifying local clusters and Moran's scatterplot for distinguishing whether the clusters detected by LISA were composed of neighborhoods with high or low job densities. Clusters with high job density were then selected as employment centers based on whether the significance value of LISA was lower than 0.1. The findings suggested that although most U.S. cities had experienced job decentralization, the monocentric structure was still the predominant form: the proportion of monocentric form among the 359 study regions in 1990, 2000 and 2010 were 56.5%, 64.1% and 57.7% respectively. In addition, the research also demonstrated that regions with polycentric form tended to be larger in size and population. This finding might explain why research listed above reached the conclusion of polycentricity, as most of the study areas selected in the research are the largest cities in America.

With the 2010 Longitudinal Employer-Household Dynamics (LEHD) data, Hajrasouliha and Hamidi (2016) evaluated the urban form of 356 U.S. metropolitan areas in the lower 48 states of the United States. The local level spatial autocorrelation statistics of Getis-Ord Gi* was employed to identify clusters with high job densities and then the urban centers were selected based on a predefined threshold of 2.5 jobs per acre. Given the fact that most American cities experienced certain degrees of dispersion, the CBDs and subcenters in many cities have become weaker than the CBDs and subcenters in a typical monocentric or polycentric form. Therefore, an extra step examining the degree of centrality and polycentricity of the metropolitan areas was involved to more clearly identify the urban form of the metropolitan areas. Major criteria used to evaluate the centrality and polycentricity included the ratio of total jobs in CBD or subcenters to the total employment in the region, the share of population around the CBD or subcenters, and the distance of the subcenter from the CBD weighted by the share of employment. The results demonstrated that over 70% of metropolitan areas experienced certain degrees of dispersion. 18 out of 356 metropolitan areas had the highest degree of centrality and zero degree of polycentricity, which were categorized as monocentric form. In addition, there were 130 metropolitan areas which also presented 0 degree of polycentricity but a lower centrality degree than the 18 metropolitan areas in the monocentric category. These 130 metropolitan areas were grouped into a pre-defined type named "centralized-dispersed", meaning that there was one CBD in the region and no competing subcenter exists, but the CBD was weaker than that in the monocentric type. Given the zero level of polycentricity and comparatively high level of centrality (still higher than other regions expect for the 18 areas in the monocentric type) of these metropolitan areas, they could still be considered belonging to the monocentric group. In this case, a total of 148 out of 356 (41.6%) metropolitan areas were in the monocentric category, which accounted for a considerable proportion among the total U.S. metropolitan areas. Besides, this research also found a positive correlation between the size of the region and tendency of being in the polycentric form.

The two studies fill in the gap in the literature for understanding the urban form in small or medium-sized regions, while most of the studies before them mainly focused on the larger metropolitan areas. In addition, they also reveal the association between the size of a metropolitan area and the tendency of being polycentric form, which can be used to explain the reason for why previous studies that focus on large metropolitan areas emphasize the polycentric nature of the U.S. cities. Although the two studies obtain different proportions of monocentric forms among all the metropolitan areas (probably due to the difference in data and methodology), they both help understand the validity of monocentric form in the United States. Besides, they also help confirm that it is still meaningful to make comparisons in the gender gap in job accessibility between monocentric form and polycentric form, given the considerable number of monocentric metropolitan areas in the United States.

2.3.2 Urban form and job-related activity-travel behavior

The relationship between urban form and people's employment-related activity-travel behavior has received widespread attention among researchers. Over the past several decades, most American cities have experienced rapid population growth and employment suburbanization. Various studies have been conducted for investigating whether and how the changes in urban areas would affect the commuting patterns and employment of urban residents. For example, two specific aspects have drawn extensive attentions, including the body of research examining if the continuous outward urban growth was associated with the increased commuting and traffic congestion that have been observed in many American cities, as well as how would the accessibility to jobs of people living in the CBD and suburban areas change as jobs continuously decentralized to the suburbs from the inner city. The former group of study usually falls under the rubric of the research of job-housing balance, and the latter is associated with the spatial mismatch hypothesis. The following part will briefly go through the two groups of research.

Job-housing balance and commuting

Job-housing balance is a concept used to describe the spatial arrangement of workers and jobs. An urban development with better job-housing balance should promote the level of heterogeneity of jobs and residence so that the spatial location of home and workplace are proximal to one another. Most cities in the United States have experienced rapid outward urban growth, which is expected to have a negative impact on travel patterns. The low-density and less compact development might indicate the spatial dispersion of jobs and houses, which would lengthen the commuting time and distance and favor automobile use. Therefore, it is believed by many that achieving a better job-housing balance would help reduce commuting and mitigate congestion. Various studies have been conducted to examine the above assumption. They mainly focus on two specific questions: 1) what is the degree of job-housing balance in an area? And 2) how is the relationship between the degree of job-housing balance and the commuting pattern in this area?

Developing an accurate way to evaluate the level of job-housing balance in a region is important in studying the relationship between job-housing balance and commuting. One of the widely used measures of job-housing balance is the ratio of the number of workers to the number of population in a local area. An area will be considered as achieving high job-housing balance when the ratio approximates 1. If the number of residents greatly exceeds the number of jobs or the number of jobs greatly exceed the number of residents, this area would be considered as being imbalanced, and it might indicate that the residents need to travel a longer distance to work. Besides, determining at what scale the job-housing ratio is measured is also significant. At the macro level (e.g. a metropolitan area) the number of jobs and residents tend to be balanced, since a region is designed as an “economically self-contained units” (Peng, 1997: 1216). If measured at the micro level (e.g. census tract or traffic analysis zone), there will be variations in job-housing balance across the region. However, it has little meaning for the policy makers to consider that residents merely work and live within the same neighborhood (Peng, 1997; Sultana, 2002). Therefore, studies usually measure the job-housing ratio at meso-level, mostly in self-defined areas with a radius which represents the “reasonable” commuting distance the researchers believe are in the study areas or a predefined subarea of the region.

For example, Wang (2000) examined the intraurban variation of the level of job-housing balance and its relationship with commuting in Chicago with the 1990 Census for Transportation Planning Package (CTPP). The research defined a floating catchment area for each traffic analysis zone (TAZ) for measuring the job-housing ratio. A circle was created for each TAZ around the TAZ’s centroid, based on which the floating catchment area was then produced that included all the TAZs of which the centroids fall in the boundary of the circle. Regression analysis was adopted to study the relationship between the job-housing ratio and commuting. The results confirmed the influence of job-housing balance on commuting that longer commutes tended to be associated with lower levels of job-housing balance. In addition, multiple floating areas have been tested in the regression models, each of which had a different radius. The one with a radius of 10-12.5 miles established the model with the best fit, which represented the “reasonable” range of commuting in the region. Sultana (2002) also studied the job-housing balance through job-housing ratio in Atlanta with the 1990 CTPP data. A floating catchment area with 7-mile radius from the centroid of each TAZ was created for measuring the job-housing ratio. Regression analysis was utilized for examining the connection between job-housing ratio and commuting time. The results demonstrated that job-housing imbalance was the most significant factor contributing to longer commutes. However, a high level of job-housing balance did not always lead to shorter commutes. Housing price also played an important role in determining where people chose to live in relations to their work locations. Workers were forced to commute longer if they were not able to afford the houses near their workplaces, even if the area had a high level of job housing balance. While the above two studies used self-defined areas for job-housing measurement, Moddarres (2011) employed the Public Use Micro-sample Area (PUMA) in three counties in Southern California, including Orange, Los Angeles and Ventura counties. Through regression analysis the research suggested a negative relationship between job-housing ratio and commuting time.

Another typical method examining job-housing balance involves comparing the observed commuting length in an area with the minimum commuting length measured based on the location of residence and workplace. Compared with the job-housing ratio which tends to be balanced if measured at macro level, this method is more suitable for exploring the job-housing balance at the regional level. For example, Horner (2007) investigated how the effect of job-housing balance on commuting has changed from 1990 to 2000 in Tallahassee, FL with 1990 and 2000 CTPP data. Through correlation analysis between the observed commuting and the theoretical minimum commuting in the region in both years, the research (Horner, 2007) revealed a strong relationship between the job-housing distribution and commuting patterns in the region. Besides, the results also demonstrated a relative stability in the extent of spatial changes of jobs and houses between 1990 and 2000 in the region. Schleith, Widener and Kim (2016) studied the change of commuting patterns and job-housing balance for 26 U.S metropolitan areas from 2003 to 2013. With the Longitudinal

Employer-Household Dynamics (LEHD) data, they found increases in both observed commuting and the theoretical minimum commuting for most of the regions between the 10 years.

The studies reviewed above have explored the relationship between job-housing distribution and commuting patterns in the metropolitan area through different quantitative methods. Although the studies have not reached a consensus on the extent to which the change in distribution of jobs and houses would contribute to longer journeys to work, they at least demonstrated that the urban form was associated with the commuting patterns. However, as the major purpose of these studies is to explore the influence of overall job-housing location on commuting, the different characteristics of jobs and workers are not taken into consideration. In other words, although they help better understand the relationship between the urban form and travel behavior, the majority of studies do not provide much information on how different types of jobs are distributed in relation to the overall urban form and how such patterns will influence employment associated activity-travel patterns. Such information is important in studies which involve the comparison of employment-related activity-travel patterns among different groups of people within the metropolitan area. Therefore, an exploration of the distribution patterns of jobs disaggregated by types will be needed in associated studies for a better understanding of their influence on job accessibility and/or commuting behaviors of different groups of populations.

Spatial mismatch hypothesis

Spatial mismatch hypothesis also deals with the spatial organization of jobs and housing locations, but it mainly focuses on the more disadvantaged job accessibility of lower-income, less-educated people living in the inner city of the region. Different from the job-housing balance approach which encompasses the distribution of the overall employment, spatial mismatch hypothesis pays special attention to jobs that are appropriate to the poor people only. Spatial mismatch hypothesis is first proposed by Kain (1968), which states that suburbanization of employment, especially in low-skilled, low-wage sectors, imposes high level of constraints on low-income inner-city residents who are not able to relocate to the suburbs (mainly due to residential segregation) for better job accessibilities. Many studies were conducted then to test the validity of this hypothesis. In an early stage, they mainly focused on the experience of minority groups (e.g. McLafferty & Preston, 1996; McLafferty, 1997; Johnston-Anumonwo, 1997), and later on the scope of the studies were extended to involve low-income populations regardless of their racial characteristics (e.g. Shen, 2001; Hess, 2005; Hu, 2015; Boschmann & Kwan, 2010).

The major indicators used to measure spatial mismatch include commuting length and job accessibility. Studies that adopted commuting length usually compare the commuting length between minority groups and their European American counterparts living in the inner city and suburbs, with the expectation that inner city minorities would experience significantly longer commutes if they face spatial mismatch. The accessibility-based research usually measures the accessibility to low-wage jobs in each place of residence of the region (such as gravity-based accessibility by census tract or TAZ), and then analyzes whether places where poor people concentrate are with high or low level of job accessibilities.

McLafferty and Preston (1996) focused on examining the degree of spatial mismatch encountered by the inner-city African American and Latino population in New York through comparing their commuting time with their European American counterparts using the 1980 and 1990 Public Use Microdata. The authors believed that commuting length reflected not only the relative location of home to workplaces of commuters but also their job and housing choices, which could be determined by multiple factors. In order to control the influence of other factors and highlight the effect of locational characters on commuting, the authors compared the observed mean commuting time with the expected mean commuting time for different population groups through partial decomposition analysis. The difference between the observed and expected commuting time would demonstrate if spatial mismatch exists. The results revealed that the African American workers had significantly longer commutes than their European American counterparts living in both the city central and the suburbs if compared by observed commuting. However, the observed commuting time for suburban African American workers did not show significant differences with their expected commuting time. A significant gap between the observed and expected commuting time was only found for the African American workers living in the inner city. The results indicated that only the inner-city African American workers were suffering from spatial mismatch problem. Although suburban African American workers had longer observed commutes than their counterparts, those were probably due to factors other than the locations of home and workspace, such as access to transportation, earnings, education, and so on.

Gottlieb and Lentnek (2001) also studied the extent of spatial mismatch for inner-city African American workers in the Greater Cleveland area. Instead of exploring the commuting patterns of residents living in the entire region, the authors picked up four neighborhoods for the comparison of commuting length between African American workers and European American workers, which included a poor African American neighborhood in the central city, a largely European American neighborhood also in the central city, a suburban African American working-class neighborhood and a suburban European American working-class neighborhood. The results illustrated that the average commuting time of inner city African American neighborhoods did not show significant difference from the two European American neighborhoods. However, the suburban African American neighborhood had significantly longer commutes than the other three neighborhoods. Accessibilities to entry-level jobs were then measured at the four neighborhoods with the gravity-based method to explain the potential reasons for the different commuting patterns between the two African American neighborhoods. The accessibility results indicated that both the African American neighborhoods had great accessibility to entry-level jobs, which were even higher than the two European American neighborhoods. Therefore, the two African American did not face spatial mismatch in terms of whether they were proximal to jobs. However, the suburban African American residents' longer commute might have indicated that they still faced certain types of choice constraints.

While the above two studies focused on the job accessibilities of African American workers, Hess (2005) and Hu (2015) paid attention to the spatial mismatch for inner-city poor people regardless of their racial characteristics using accessibility-based methods. With 2000 census data, Hess (2005) investigated the job accessibilities to low-income residents in Erie and Niagara Counties in western New York State. The study suggested that there were more low-income populations residing in the central cities than in the suburbs. Besides, the majority of low-wage jobs were distributed within and around a short distance from the central cities. It was not surprising to find that the central cities had significant advantage in accessing low-wage jobs than the suburbs, given the large spatial concentration of low-wage jobs and low-income residents there.

Hu (2015) carried out a longitudinal analysis of the changes in accessibilities of poor populations to low-wage jobs, as well as the accessibility disparities between them and the non-poor populations in Los Angeles from 1990 to 2007-2011. Through gravity-based accessibility measures, the research suggested that the inner-city poor people had greater job accessibilities than their suburban counterparts, but the advantage declined from 1990 through 2007-2011 due to the job suburbanization. The non-poor people had higher accessibility to their skill-matched jobs than the poor counterparts, no matter whether they lived in the city or the suburbs. However, the greatest accessibility gap between poor and non-poor was found in the inner-city. The results also suggested that the jobs appropriate for the non-poor people also experienced job suburbanization, and the accessibility of non-poor people also declined in the inner city but inclined in the suburbs. In addition, the non-poor jobs dispersed in a faster speed than the low-wage jobs from the city to suburbs. As a result, the accessibility gap between poor and non-poor people shrank in the inner-city but widened in the suburbs between 1990 and 2007-2011.

The studies reviewed above were conducted in different years and locations, with varied data and methods. The mixed results obtained from the studies might have partially demonstrated the varied distribution patterns of different jobs and the paces of job suburbanization in the American cities. Compared with the studies related with the job-housing balance and commuting, the spatial mismatch hypothesis studies have more similarities with the gender difference in accessibility to jobs which this dissertation would like to study. Both of them explore the more disadvantaged accessibilities to jobs of a specific group of population compared with another group. However, the spatial mismatch hypothesis employs place-based accessibility measures, which produces homogeneous accessibility results for everyone living in the same area. It is suitable for studying the difference between poor and non-poor people, because residential segregation is observed between the two groups, which is assumed as one of the major causes of poor people's low job accessibility by the spatial mismatch hypothesis. However, this method will cover the different accessibility between men and women who do not show obvious residential segregation (especially for married couples who are supposed to live in the same household). Therefore, a methodology that is more suitable for examining gender difference in accessibility will be developed in this dissertation.

2.4 Summary

The majority of the previous research that studies men and women's different employment opportunities from spatial aspects mainly focused on women's persistent shorter commute than men. Mostly through quantitative analysis, the studies find out that two factors majorly contribute to women's more disadvantageous accessibility to jobs and hence their segregation in female-dominated occupations. One of the factors is related with women's conventional gender roles that decrease the amount of time for traveling to work. The other factor is associated with the uneven distribution of different types of occupations across the space. While the studies significantly contributed to reveal the causes of women's limited accessibility to certain types of jobs, they also suffer from a few of flaws which lead them not to be able to accurately evaluate the gender disparities between men and women's accessibility to jobs across the metropolitan area. The major flaws include the inability to capture the integrated effect of time and space on individual's accessibility to jobs and hence to develop an accurate measure to evaluate the job opportunities men and women are able to access under their different spatio-temporal constraints. The other drawback of the studies relates to the lack of power to evaluate the intraurban and interurban variations in the gender gap in accessing job opportunities.

Time geography is a constraint-oriented framework which provides an effective and efficient platform for investigating human activity patterns in time and space in an integrated way. The space-time prism, one of time geography's analytical tools, is well suited to measure the space-time accessibility in terms of the opportunity set that can be physically accessed by an individual under the space-time constraints. The time-geographic principles and the space-time prism construct have been widely applied to explore individuals' accessibilities to various urban opportunities. However, limited research has employed them to analyze the disparities between men and women's space-time accessibility to jobs.

Studies related to urban form are also reviewed. One purpose of reviewing the studies is to obtain a clearer picture of the development of the spatial distribution patterns of the U.S. metropolitan areas. According to the studies, although many large cities demonstrate strong polycentric characteristics, there are still a considerable number of metropolitan areas in monocentric form. The other purpose is to achieve a better understanding of the connections between urban form and employment-related activity-travel behaviors. Between the two groups of associated studies, the spatial mismatch hypothesis shares more similarity with the gender difference in employment, which is the main topic of this dissertation. Both of them focus on the more disadvantaged job accessibilities of a specific population group compared to another group. However, the place-based accessibility measures utilized by the spatial mismatch hypothesis studies cannot capture the difference in accessibility to jobs between men and women, since there are no obvious patterns of residential segregation between genders.

Therefore, this research aims at developing a new methodology to explore the gender difference in employment opportunities accessibility. The new methodology will be based on the time-geographic framework, which supports an integrated way to investigate the effect of gender role constraint and the uneven distribution of different types of jobs on men and women's accessibility to jobs. A conceptual framework will be established to help understand the different spatio-temporal constraints applied to men and women and their impacts on men and women's employment activities. Space-time accessibility measures will be established for evaluating and comparing the patterns of job accessibilities for men and women based on the space-time prism construct.

CHAPTER III

METHODOLOGY

As suggested by the previous literature, women's traditional gender roles as well as the job distribution patterns are the major factors that cause women's disadvantaged accessibility to jobs and eventually lead to their segregation in female-dominated occupations. However, the methods used by the commuting-based research are not able to capture the mechanism on how these two factors affect men and women's accessibility to jobs in an integrated way, and hence it is necessary to develop a more effective measure to evaluate the job opportunities men and women can access under their different levels of space-time constraints. Time geography provides an elegant platform for exploring people's activity patterns in space and time. A number of applications have applied time geography concepts and constructs to compare the daily activity patterns between men and women. However, there has not been sufficient effort to take the advantage of the time-geographic framework to study the gender difference in space-time accessibility to jobs. Aiming at enhancing the literature in this field, this dissertation will introduce a new time geography based methodology for job accessibility measure to investigate the gender accessibility difference. As a constraint-oriented approach, time geography focuses on the space and time limitations of individuals participating in specific activities, which are closely related to the activity patterns of the individuals. Therefore, this chapter will first take an analysis on men and women's daily activity patterns and hence provide a comprehensive understanding on the different space-time constraints and their impacts on work activities. Space-time accessibility measures will then be proposed to evaluate the potential job opportunities men and women can access based on their different space-time constraints on work activities.

3.1 Conceptual Framework

An individual's daily activities can be generally classified into three broad categories (Bhat & Koppelman, 1993): subsistence, maintenance, and leisure activities. Subsistence activities mainly refer to employment or employment-related business which is critical to providing financial support for pursuing maintenance and leisure activities. Maintenance activities are associated with the purchase and consumption of goods/services to meet family/personal physiological and biological needs. More specifically, maintenance activities include personal care (sleeping, eating, personal medical care, and travel related personal care) and household responsibilities (housework and taking care of family members) (Zhou et al., 2012). Leisure activities pertain to social and recreational pursuits to satisfy cultural and psychological needs. Among the three categories of activities, subsistence and maintenance activities have greater significance to the basic standard of individuals' daily lives while leisure activities are less obligatory in nature. In most of the research that is associated with individuals' daily activity patterns, subsistence and maintenance activities are assumed to have higher priorities over leisure activities, and there are no significant gender difference in the priorities between leisure activities and the other two activities (e.g. Manrai & Manrai, 1995; Moen & Yu, 2000; Christensen & Schneider, 2010; Ren & Kwan, 2009; Schieman & Glavin, 2008; Zhou et al., 2012).

Subsistence and maintenance activities are essential for supporting the basic standard of individuals' daily lives. They often bring time pressure to individuals, since fulfillment of them usually requires a significant amount of time. People need to develop certain strategies to cope with time pressure, which usually involve the division of responsibilities between family members on employment and household activities. Historically, the paid work and household responsibilities have been divided based on gender in the United States, with men primarily responsible for the paid work, while women fully focusing on the household responsibilities (Sayer et al. 2004; Oates & McDonald, 2006). Since 1960s, an increasing number of women have been entering the paid work, and a considerable proportion of them were in full-time jobs (Lyonette & Crompton, 2015). As a result, couples face the challenge to complete three "jobs", including two at the workplace and one at home (Moen &Yu, 2000). Changes in the allocation of domestic labor have been made to cope with this new situation. It is documented that men have increased the time they spend on housework and childcare, while women have devoted less time to housework (Bianchi et al. 2006; Coltrane, 2009; Hook, 2010; Kan et al. 2011). However, the typical labor division mode for American families are still gendered, with the husbands focusing on the employment activities while the wives are responsible for most of the domestic work (Moen &Yu, 2000). It can be considered as a modified version of the conventional male breadwinner/female homemaker model. The employment activities usually have higher priority to the household responsibilities for male workers in families of the modified breadwinner/homemaker model. Driven by the social norms of femininity and maternity, women tend to assign lower priorities to subsistence activities than to household responsibilities, and continue to take the lion share of domestic work (Bianchi et al. 2000; Bianchi & Milkie, 2010; Craig & Mullan, 2011; Estes, 2011; Kan et al. 2011;Schneider, 2011; Lyonette & Crompton, 2015; Geist & Ruppanner, 2018)

In general, the variety in the priorities of work and household activities for men and women shapes the different daily activity patterns between genders, which are demonstrated in Figure 3.1. For men, personal care activities have the highest priority, because they are the activities that fulfill human physiological and biological needs. They are followed by the employment activities. The activities such as household and leisure activities are with least priorities for men. For women,

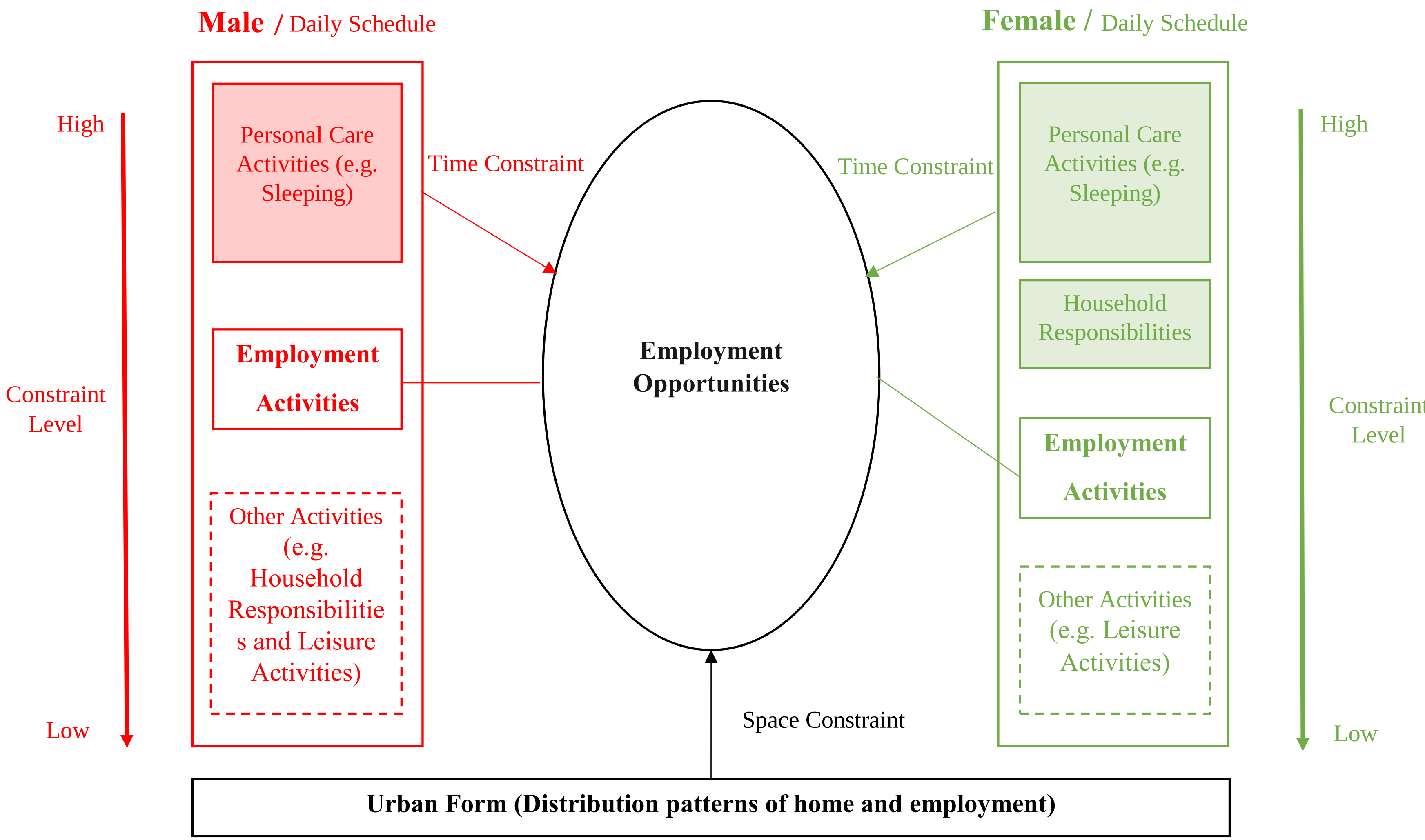


Figure 3.1 Different daily activity patterns between men and women

personal care activities are also with the highest priorities. However, different from the activity patterns of men, women's household activities have higher priorities than work, due to women's status normed by conventional gender roles. Finally, activities such as leisure activities are with the least priorities for women.

The different daily activity patterns between men and women further define the gender gap in their time budgets for conducting employment activities. Time is a finite resource for human beings. Each activity takes time and the time spent on one activity is hardly to be used on the other activity (except for activities in the virtue space). Therefore, how much time can be spent on an activity is significantly influenced by the activities that have higher priorities over it. In this case, according to men and women's different activity patterns in terms of the priorities of activities, men's time-budget for work is mainly dependent on the time spent on personal care activities, while women's time budget for work is not only dependent on the time they spend on personal care activities but also affected by their household activities. According to BLS (2018c), men and women spend similar amount of time on personal care activities (with men spending 8.69 hours daily while women spending a slightly higher time of 9.15 hours per day). Therefore, after counting for the household activities, the maximum amount of time women can spend on work is less than men.

In addition, activities are distributed across the city. Except for those who work at home, the majority of individuals' employment activities are located at a different place from home where they conduct most of the maintenance activities. Traveling among them also takes time. How long it takes to move from one activity to another depends majorly on the distance between the locations of the two activities, the traffic condition and the transportation mode the individual utilizes. While the transportation mode is mainly related with individuals' socio-economic status or personal preference, the distance between activities and the traffic condition is closely associated with the structure of the specific metropolitan area where the individuals reside and work. According to previous literature, most cities have experienced significant outward growth, indicating a more dispersed spatial distribution of jobs and housing locations. As a result, traveling between home and jobs takes longer time and the traffic becomes more congested. Women have smaller time budgets for work than men due to their household responsibilities. Therefore, the employment opportunities women can access will be less than men within their more limited time budget. Besides, the difference in the number of job opportunities women can access from men varies by place. Living in a place that offers faster travel and shorter distances among activities would improve the number of accessible job opportunities to women and in turn decrease the gender disparities in accessing jobs.

3.2 Measures of Accessibilities to Employment Opportunities

This section will propose measures to evaluate the potential job opportunities men and women can access given their different space-time constraints and estimate the gender disparities in space-time job accessibilities. The measures will be developed based on the space-time prism construct of the time-geographic framework. The space-time prism represents the three dimensional (including two geographical dimensions and the third time dimension) space that individuals are able to occupy or move around due to their space-time constraints. In other words, the space-time prism defines the space-time limits of what is accessible to individuals. Whether an individual can access an activity is dependent on whether the space-time location of the employment activity is within the space-time prism. Therefore, this research will identify whether an individual can access an employment activity by comparing the extent of the individual's space-time prism with the space-time location of the employment activity. The employment opportunity will be considered accessible if it is within the space-time prism. All the employment opportunities that fall in the boundary of the space-time prism are the collection of the potential employment activities individuals can access. The extent of a space-time prism is framed by the locations and time of the fixed activities, which are defined as activities whose time and location cannot be easily altered. In this research, the fixed activities refer to the activities which have higher priorities to individuals over employment activities. Since men and women have different daily activity patterns in terms of activity priorities, the fixed activities that determine the extent of the space-time prism are different for men and women. In particular, the space-time prism of men will be framed by time and locations of personal care activities, but the space-time prism of women will be determined by personal care activities and/or household responsibilities.

Two groups of measures are established as follows, which evaluate the space-time accessibilities to employment opportunities at individual and local level, respectively. The first group of measures (including equation (1) through equation (3)) are used to calculate the potential job opportunities an individual can access given his/her space-time constraint on employment activities. Equation (1) identifies whether a job opportunity in the metropolitan area can be accessed by an individual by examining whether the job falls within the extent of the space-time prism in both time and space dimensions. To determine the spatial extent of the space-time prism, this research assumes that there are two fixed activities. For men, the two fixed activities should be in the category of personal care activities. For women, they should be either personal care activities or activities which fulfill the household responsibilities. The first and second fixed activities have departure and arrival times. The employment activities also have start and end times. In addition, it is highly possible that the fixed activities and the employment activities are distributed at different locations. Therefore, for an individual *i* living in a metropolitan area *C*, whether a job *j* in *C* can be accessed by individual *i* (denoted as A_j^i) is measured as:

$$A_j^i \begin{cases} = 1 \quad & if \ \ t_{aj} \leq (t_s - t_a) \ \propto \ t_{jb} \leq \ (t_b - t_e) \\ \\ = 0 & if \ else \end{cases} \tag{1}$$

where A_j^i=1 represents *j* being accessible, A_j^i= 0 represents *j* being not accessible, t_s is the start time of *j*, $t_e$is the end time of *j* ($t_s < t_e$), t_a is the end time of the first fixed activity *a* until when the individual cannot leave for work, t_b is the start time of the second fixed activity *b* before when the individual must arrive at b, t_{aj} is the time it takes to travel from a to j, t_{jb} is the time it takes to travel from j to b. It is interpreted that a job is considered accessible only if: 1) the individual can arrive at the job location before the job starts after completing the fixed activity a and traveling from a to this job; and 2) the individual can arrive at the fixed activity b after completing the job before b starts and then traveling from the job to b. This equation is the foundation of the space-time accessibility measures developed in this research. All the following equations are built upon it.

Based on the identification of the accessibility of each single job opportunity to an individual, the overall space-time accessibility to employment activities can be measured for him/her. In general, two different methods have been applied to measure the space-time accessibility (Miller, 2004). One views all the opportunities that are within the space-time prism as equally accessible and hence the space-time accessibility is calculated as the total count of those opportunities. The other takes the visit probability into account: while all the opportunities that are within the space-time prism are accessible, some are more likely to be visited (e.g. the opportunities which locate more proximal to the fixed activities are more likely to be visited). In this case, opportunities will be assigned different weights according to their visit probability when calculating space-time accessibilities. In this research, the formal method is chosen to reduce the complexity of computation and interpretation. Therefore, the space-time accessibility to job opportunities will be the total number of jobs that are accessible to the individual. In particular, if *J* is the set of jobs in *C*, then the total number of employment opportunities that are accessible to i, denoted as A^i, is measured as:

$$A^i = \sum_{j \in J} A_j^i \qquad (2)$$

Equation (3) measures the total number of jobs an individual can access disaggregated by occupation types. It helps evaluate the types of occupations to which the individual will have higher accessibility given his/her space-time constraints. Divide *J* into *O* groups by occupations types, and denote each occupation group as J_o $(o = 1,2, \ldots, O)$. The number of jobs that are accessible to i by occupation types A_o^i is measured as:

$$A_o^i = \sum_{j \in J_o} A_j^i \qquad o = 1,2, \ldots, O \quad (3)$$

The second group of measures (Equations (4) – (9)) are used to examine the gender difference in job accessibilities at the local level in a metropolitan area. Equations (4) and (5) measure men's accessibilities to the overall employment opportunities and the employment opportunities disaggregated by occupation types respectively at a certain place of the metropolitan area. The local units can be either arbitrarily defined units or already existing ones, such as census tracts or traffic analysis zones. Similarly, Equations (6) and (7) measure women's accessibility to the overall employment opportunities and the employment opportunities disaggregated by occupation types respectively at the places. The results produced by the measures will provide information on the spatial distribution of male and female workers' accessibility to jobs across the metropolitan area. Such information can be used to analyze the disparities in accessing jobs among individuals living in different parts of the metropolitan areas within gender groups, hence the relationship between the gender accessibility differences and the structure of the metropolitan area.

Divide the metropolitan area C into N spatial units (e.g. census tracts), each denoted as C_n $(n = 1,2, \ldots, N)$. Denote the numbers of men and women living in each spatial unit as m_n and f_n. Therefore, the average number of jobs that are accessible by men in unit C_n, denoted as A_n^M , is measured as:

$$A_n^M = \frac{\sum_{i=1}^{m_n} A^i}{m_n} \qquad \text{if } i \text{ lives in } C_n \text{ \& } i \text{ is male} \quad (4)$$

and the average number of jobs that are accessible by men by occupation types in unit C_n, denoted as A_{no}^M, is measure as:

$$A_{no}^{M} = \frac{\sum_{i=1}^{m_n} A_o^i}{m_n} \qquad \text{if } i \text{ lives in } C_n \text{ \& } i \text{ is male} \qquad (5)$$

The average number of jobs that are accessible by women in unit C_n, denoted as A_n^F , is measured as:

$$A_n^F = \frac{\sum_{i=1}^{f_n} A^i}{f_n} \qquad \text{if } i \text{ lives in } C_n \text{ \& } i \text{ is female} \qquad (6)$$

and the average number of jobs that are accessible by women by occupation types in unit C_n, denoted as A_{no}^F, is measure as:

$$A_{no}^F = \frac{\sum_{i=1}^{f_n} A_o^i}{f_n} \qquad \text{if } i \text{ lives in } C_n \text{ \& } i \text{ is female} \qquad (7)$$

Two measures (Equations (8)-(9)) that explore the gender difference in the accessibility of the overall jobs and jobs disaggregated by occupation types at the local unit are also proposed. The gender difference in accessing the overall jobs in C_n, which is denoted as R_n, is measured as the ratio of the number of overall jobs women can access in C_n over the number of overall jobs men can access in C_n:

$$R_n = \frac{A_n^F}{A_n^M} \qquad (8)$$

and the gender difference in accessing jobs in an specific occupation J_o in C_n, which is denoted as R_{no} , is measured as the ratio of the number of jobs in occupation J_o women can access in C_n over the number of jobs in occupation J_o men in C_n can access :

$$R_{no} = \frac{A_{no}^F}{A_{no}^M} \qquad (9)$$

For both equation (8) and equation (9), a ratio of "1" indicates equal job opportunity between men and women, a ratio between 0 to 1 demonstrates women's less opportunity than men, and a ratio larger than 1 illustrates women's higher accessibility than men at the local area. While equation (4) through (7) are used to investigate the within-gender disparity in job accessibilities among various locations in the metropolitan area, equation (8) and (9) will allow for detecting the different job accessibilities between gender groups across the metropolitan area and hence provide a better understanding of the relationship between the urban structure and the gender difference in accessing jobs.

The measures proposed above evaluate men and women's accessibility to jobs given their different time budgets for work as well as the distribution patterns of jobs in the metropolitan area. The results obtained from the measures allow for analysis of the spatial distributions of the potential jobs men and women are able to access at different locations in the metropolitan area, based on which the influence of urban structure on gender disparities in accessing jobs can be investigated. In the following chapter, the measures will be applied to a scenario-based analysis to demonstrate its usage as well as the feasibility on exploring the relationship between urban structure and gender equity in accessing jobs.

CHAPTER IV

SCENARIO-BASED ANALYSIS ON SPACE-TIME ACCESSIBILITIES TO EMPLOYMENT OPPORTUNITIES

As the most typical urban forms for the U.S. cities, monocentric and polycentric forms represent two typical spatial distribution patterns of employment opportunities in cities. According to previous literature (e.g. Wang, 2000; Sultana, 2002; Moddarres, 2011; and Hu, 2015), the two urban forms have distinct effects on the accessibilities to various urban activities and travel behaviors for different population groups. However, there has been limited effort on studying the connection between urban form and the accessibility to employment activities between men and women given their different time budgets for traveling to work. This chapter will focus on comparing how monocentric and polycentric urban forms affect men and women's space-time accessibilities to jobs. In particular, a series of simulated urban models will be generated to represent variations of employment distribution patterns of monocentric and polycentric urban forms. These predefined models will then be used for exploring the influence of the urban forms on men and women's job accessibilities. The space-time accessibility measures developed in Chapter III will be employed to calculate the number of jobs men and women are able to access, as well as the gender ratio in job accessibilities in each model. The results will be used to portray the job accessibility discrepancies between men and women in monocentric and polycentric forms, and evaluate how different urban forms will affect gender equity in accessing jobs.

4.1 Definition of Simulated Urban Models

Two groups of city models are designed respectively in this research to represent the different job distribution patterns in the monocentric and polycentric urban forms. According to the previous literature (Arribas-Bel and Sanz-Gracia, 2014), the monocentric form is the major urban form during the early development stage of American cities. A monocentric city has only one economic center, which is called the CBD and holds a great proportion of jobs in the city. With rapid population growth and transportation innovations, a large number of cities have experienced population dispersion and job decentralization. As a result, the proportion of jobs in the CBD decreases and new employment centers are formed. The new urban form with multiple centers is called a polycentric form, and the new employment centers that are outside the traditional CBD in a polycentric city are called employment subcenters.

This research will follow the conceptions of urban forms to develop the basic design of the city models. The models with a monocentric form will have one employment center where a high proportion of jobs concentrate. For the polycentric models, three centers are arbitrarily designed, which include one traditional CBD and two subcenters. In reality a polycentric city can have far more centers. However, three centers should be sufficient for comparing the influence of different urban forms on men and women's space-time accessibilities to employment opportunities. In addition, multiple models will be created under each type of urban form to present the possible job distribution patterns in real city cases.

The two types of urban forms will be presented in a series of simulated cities that are modeled by a matrix of grids. In order to emphasize the major difference between monocentric and polycentric form, the grids for both urban forms are designed to have the same size and equal number of total jobs. Both urban forms will contain 2.5 million workers distributed across a 15 x 15 grids. Each grid is square-shaped, with a side length of 10 km. Thus the total area of each form is 22,500 square kilometers (km). For the purpose of simplicity, all 2.5 million workers are local residents. No in-bound (workers working inside but living outside of the city) or out-bound (workers working outside but living inside of the city) commuting exists in the grids.

4.1.1 Monocentric urban form design

Twelve models are generated to illustrate the different scenarios of a monocentric urban form. According to the definition of a monocentric form, all of the models will have one employment center, namely the CBD. Besides, the location of the CBD will be arbitrarily defined at the innermost center of the grid, which accords with the location of the CBD in the earliest state of the monocentric model proposed by von Thünen (1966). Except for the location of the CBD, the spatial distribution patterns of employment opportunities in the 12 models will vary in the following two dimensions: *degree of concentration* and *size of the CBD*.

The degree of concentration refers to the proportion of jobs concentrating in the CBD. The larger of the number of jobs distributed in the CBD, the higher the degree of concentration of the model. In a standard theoretical monocentric form, all employment opportunities should be located in the CBD. However, in a real city, there should be a certain amount of jobs dispersed to the areas outside the CBD. Usually a CBD with a higher degree of concentration is more dominating and leaves less jobs distributed in the areas outside the CBD. This research defines four degrees of concentration values for the monocentric models, which are 15%, 30%, 45%, and 60% respectively. Among the models with the four designed values, the ones with a 15% of degree of concentration have the weakest CBD with the least number of jobs distributed in the CBD. In contrast, the models with a 60% degree of concentration have the largest proportion of jobs concentrating in the CBD.

The size of the CBD is the other factor used in this research to determine the job distribution patterns in the monocentric model. The size of the CBD in most cities accounts for only a small portion of the city. This is why this area is called as a “district”. For instance, the size of the CBD in the Chicago metropolitan area accounts for less than 1% of the total area of the region. However, in a few special cases, the CBD can take up much larger spaces. For example, the Beijing metropolitan area has a vast CBD which accounts for around 7% of the total area in the region and holds almost 60% of the city’s jobs (Huang, Liu and Zhao, 2015). Since the variation in the CBD size can result in different job accessibility patterns for individuals living in the cities, multiple CBD sizes are included in the models of this research. In particular, three CBD sizes are assigned to the models, which are one grid, nine (3 x 3) grids, and 25 (5 x 5) grids. They indicate a CBD accounting for 0.4%, 4% and 11% of the total area of the models, respectively. In models with identical degrees of concentration, the increase in the CBD size will lead to a decrease in the job density of the CBD. Therefore, among the models with the three designed CBD sizes, the ones in which the CBD is composed of one grid have the highest job density in the CBD, while the ones in which the CBD contains 25 grids have the lowest job density. In addition, the expansion in the size of the CBD will reduce the areas outside the CBD, and hence increase the job density in the areas outside the CBD. Therefore, the models with the CBD size of one grid have the lowest job density in the outside area, while the models with the CBD size of 25 grids have the highest job density in the outside area.

The four concentration degrees together with the three CBD sizes yield a total of 12 combinations of employment distribution patterns, which are demonstrated in maps in Figure 4.1. As aforementioned, each of the two factors will respectively influence the job density in each part of the models, while the combination of the two factors may further intensify or weaken the influence. For example, the increase in the degree of concentration and the decrease in the size of the CBD will both enhance the job density in the CBD and reduce the job density in the areas outside the CBD. Therefore, the one with a 60% degree of concentration and the size of CBD of one grid has the highest job density in the CBD while the lowest in areas outside the CBD. As a result, the disparities in job densities between the two parts are the largest among the 12 models. In contrast, the one with a 15% degree of concentration and the size of 25 grids has the lowest job density and the highest in areas outside the CBD, and hence the smoothest transition from the CBD to the areas outside the CBD. Such differences in the distribution patterns among the 12 monocentric models are expected to produce distinct job accessibility patterns for men and women.

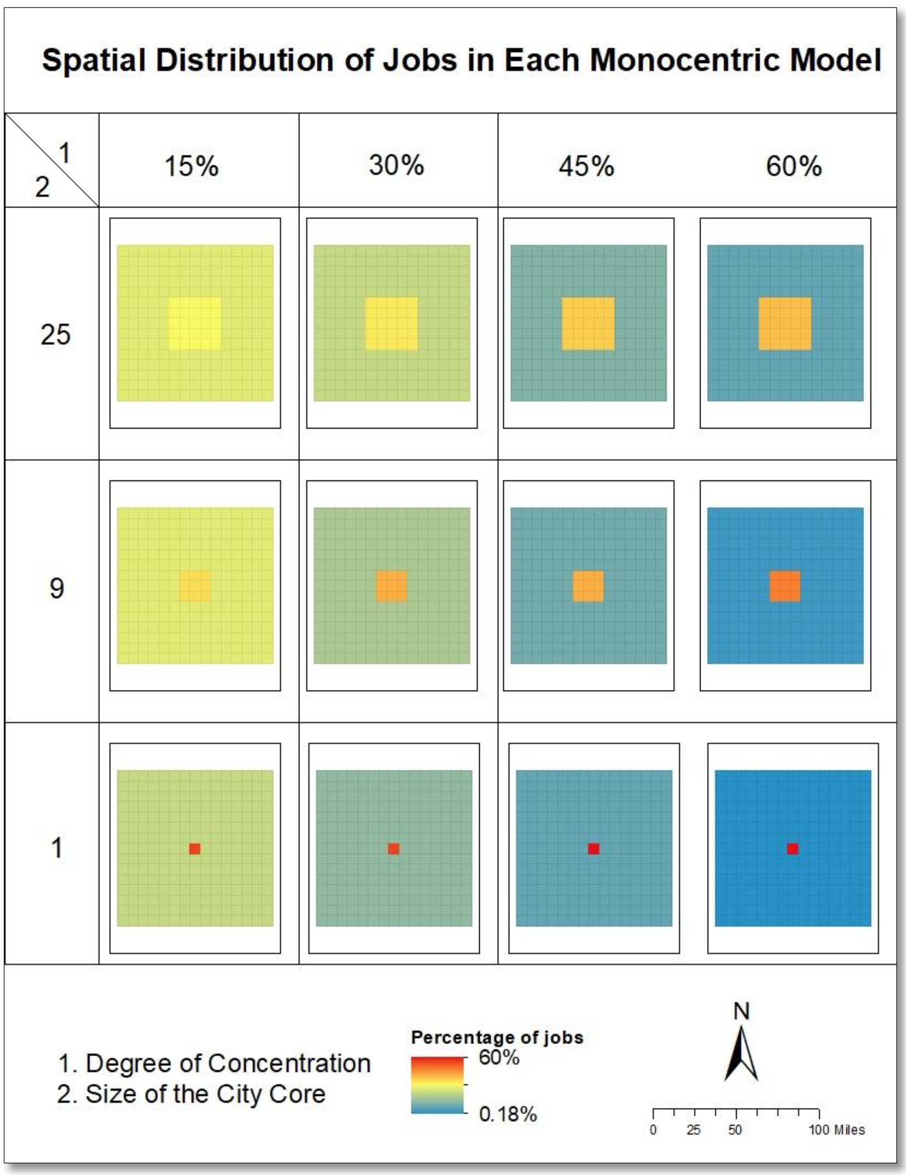


Figure 4.1 Spatial distribution of jobs in each monocentric model

4.1.2 Polycentric urban form design

This research also creates 12 models for the polycentric form. The spatial distribution of jobs in these 12 models will mainly vary in two aspects: 1) the locations of the employment centers, and 2) the amount of jobs distributed at each center.

As aforementioned, each of the polycentric models contains three employment centers, including one traditional CBD and two subcenters. In all 12 polycentric models, the location of the CBD will remain the same as the location of the CBD in the monocentric models, which is at the innermost center of the grids. Regarding the locations of the two subcenters, two arrangements are designed. In the first arrangement, the two subcenters are located along the Northeast (NE) – Southwest (SW) diagonal line of the grids, and the two subcenters will be named as the NE and SW center respectively. The second arrangement is the two subcenters placed at the north side of the traditional CBD in the grids. Accordingly, the names of the two subcenters will be NE and NW respectively. In both arrangements, the two subcenters are within the same distance from the traditional CBD. The design of these two spatial arrangements of the centers allows for an investigation on how the location shifts of the subcenters may affect the job accessibilities at different places of the city.

Besides the spatial arrangements of the centers, the amount of jobs distributed at each center also varies among the models. In the monocentric form design, the models have various degrees of concertation at the center, which allows an investigation on how job concentration at CBD can affect job accessibility. Focusing on how job distribution across multiple centers can impact job accessibility, the polycentric models are designed to have a fixed total amount of jobs to be distributed to the multiple centers, but vary on the amount of jobs to be assigned to each center. The following steps are taken to create the design:

- 30% of the total jobs in the model is chosen as the total amount of jobs to be located in the three employment centers. Since it is one of the degree of concentration values in the monocentric models, it is made possible to compare which urban form would provide more equal job accessibility between genders when the number of employment opportunities in the employment center(s) are identical with each other.
- Three major types of relations among the three centers are defined in terms of how the 30% of jobs are distributed among the centers: a) one center is in the dominating position which holds the largest portion of jobs among the three centers, and the other two centers have different amount of jobs; b) one center is in the dominating position which holds the largest portion of jobs among the three centers, and the other two centers have equal amount of jobs; and c) the 30% of jobs are equally distributed among the three centers with each accounting for 10% of jobs.
- Two groups of values are arbitrarily assigned to the centers in type a and type b in the above step respectively. For type a, the dominating center contains 14% of jobs and the other two centers respectively have 10% and 6% of jobs. For type b, the dominating center also contains 14% of jobs but the other two centers equally contain 8% of jobs. The values are chosen based on two criteria: 1) the job density in each center is higher than the job density in the non-center area; and 2) there are certain gaps in the amounts of jobs among the centers, so that the influence of the variations in the degrees of concentration among the centers on men and women's job accessibilities can be easily detected.

Given the above settings, there are 10 different distribution combinations among the three centers for each of the arrangement of the locations of the subcenters. However, some pairs of distributions are symmetric with respect to either the diagonal line or the line passing through the CBD in the north-south direction. For example, when the subcenters and the CBD are located along the diagonal line, the following two distributions are symmetric along the SW-NE diagonal line: 1) the CBD contains 14% of jobs, the SW subcenter contains 10% and the NE subcenter contains 6% of jobs; and 2) the CBD contains 14% of jobs, the SW subcenter contains 6% and the NE subcenter contains 10% of jobs. Therefore, one of the distributions is removed from each pair to reduce the redundancy of the models. Finally, six distributions remain in each arrangement, which is shown in Table 4.1.

Table 4.1. The amount of jobs distributed in each center in polycentric models

Locations of the Centers	**Relations among the Centers**	**Proportion of Jobs in Each Center**		
		CBD	**NE**	**SW**
Centers located along the diagonal line	**CBD = NE = SW**	10%	10%	10%
	CBD > NE =SW	14%	8%	8%
	CBD > NE > SW	14%	10%	6%
	SW > CBD > NE	10%	6%	14%
	SW > NE > CBD	6%	10%	14%
	SW > NE = CBD	8%	8%	14%
		CBD	**NE**	**NW**
Centers located at the north side	**CBD = NW = NE**	10%	10%	10%
	CBD > NW = NE	14%	8%	8%
	CBD > NW > NE	14%	10%	6%
	NW > CBD > NE	10%	6%	14%
	NW > NE > CBD	6%	10%	14%
	NW > NE = CBD	8%	8%	14%

The spatial distribution of employment opportunities in the 12 polycentric models are presented in Figure 4.2. Because the total amount of jobs in the three centers is consistent across the models, the job density in areas outside the centers also remain constant. Therefore, the difference in the general spatial distribution of jobs among the polycentric models does not look as significant as the difference among the monocentric models. Based on the maps in the figure, the majority of the differences among the 12 models lie in the locations of the subcenters and the job densities in the centers.

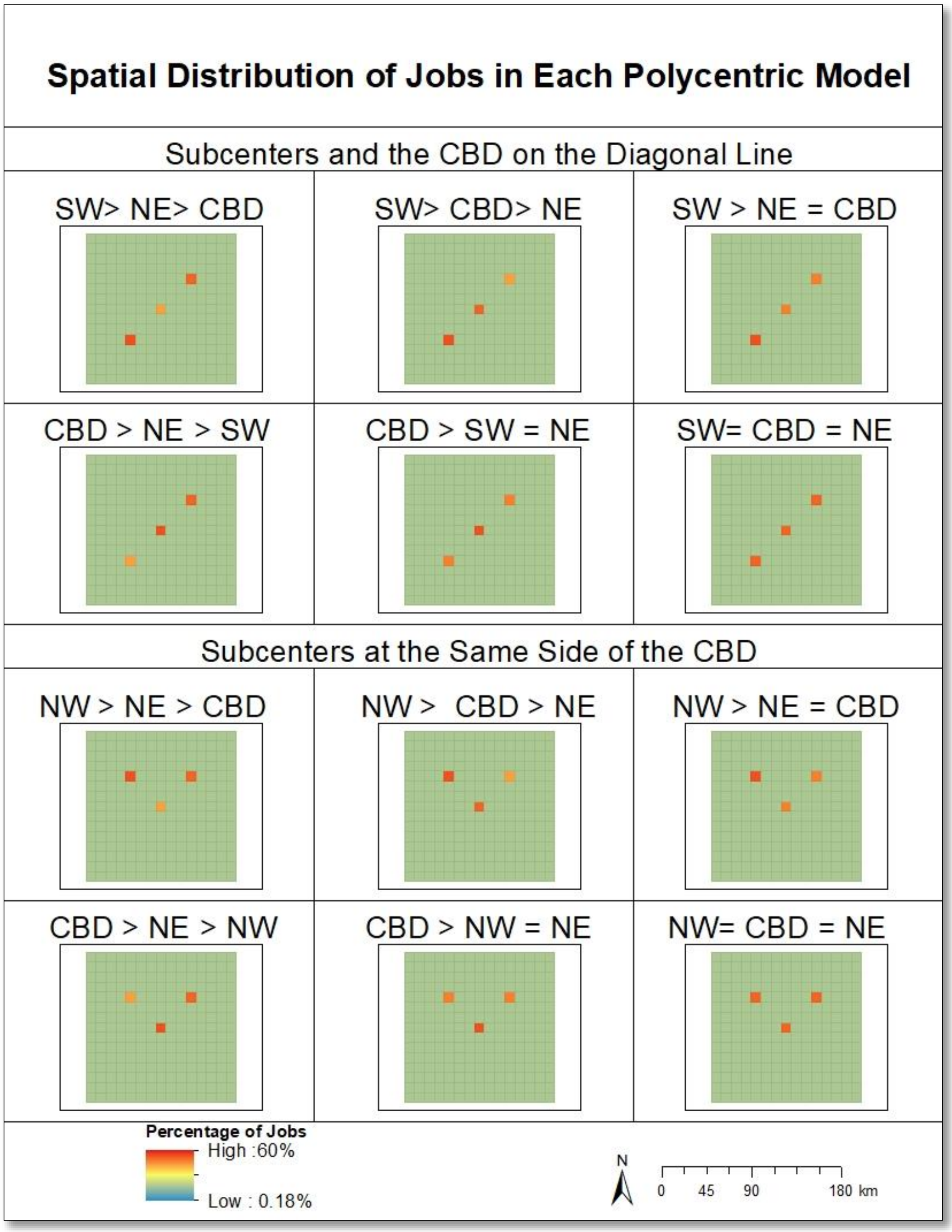


Figure 4.2 Spatial distribution of jobs in each polycentric model

4.1.3 The design on time budgets for traveling to work

For simplicity, this research assumes that all men have the same time budget of 60 minutes for traveling between home and work, while all women have 30 minutes. In addition, this research also hypothesizes that all workers living in the cities travel in straight-line distance at a constant speed of 60 km/h between the centroids of the grids. The number of jobs men and women are able to access, as well as the gender difference in job accessibility in each cell in different models are calculated based on the methodology developed in chapter III. The results will be presented and analyzed in the next section.

4.2 Results

4.2.1 Accessibility patterns for men and women in monocentric models

Figure 4.3 and 4.4 demonstrate the spatial distributions of job accessibilities in each monocentric model for men and women respectively. In particular, the accessibility value presented in the maps is the percentage of jobs men/women can access at each grid of the model. It is calculated as the number of jobs men/women can access in each grid divided by the city's total number of jobs. The purpose of the conversion from the number to the percentage of jobs individuals can access is to place all the accessibility values on the same scale. It will be easier to compare the distribution patterns of accessibilities among different models and also between men and women.

The maps indicate that the general distribution patterns for both gender groups in all models demonstrate a strong 'monocentric' character, as the percentage of accessibility values decrease monotonically from the center to the edge of the models. On the one hand, individuals living at or close to the center are able to reach the CBD area, which contains significantly higher proportions of jobs than other locations in the city. Therefore, they are able to access a higher amount of employment opportunities than others. On the other hand, a part of the job search area is outside the boundary of the city for those living close to the periphery. Their job accessibilities are even lower than those living in places between the CBD and the city fringe. Comparing women's maps with men's, more frequent blue color is found on women's maps. It indicates much lower accessibilities for women than for men, which is mainly due to women's lower time budget for traveling to work.

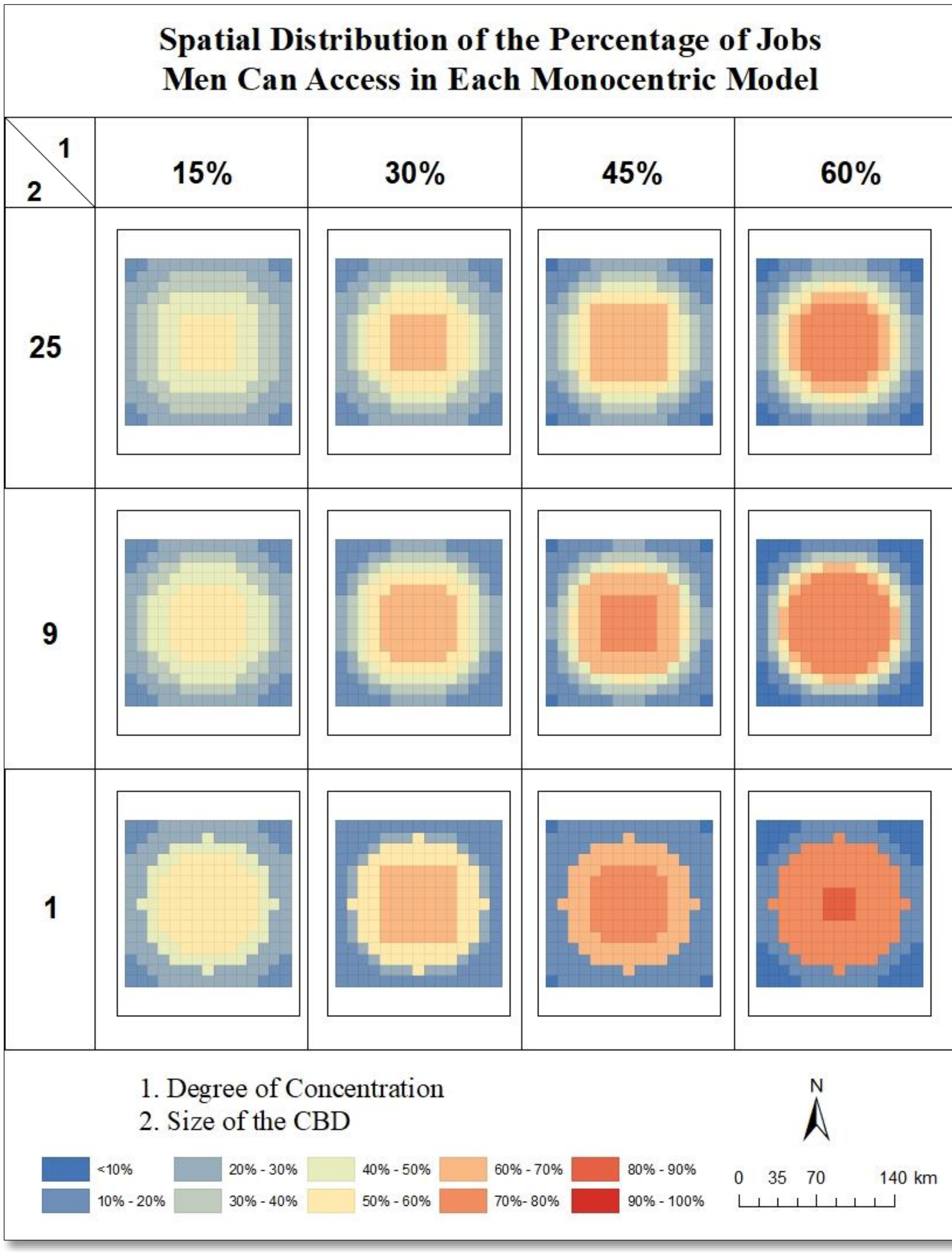


Figure 4.3 Spatial distribution of men's accessibilities in each monocentric model

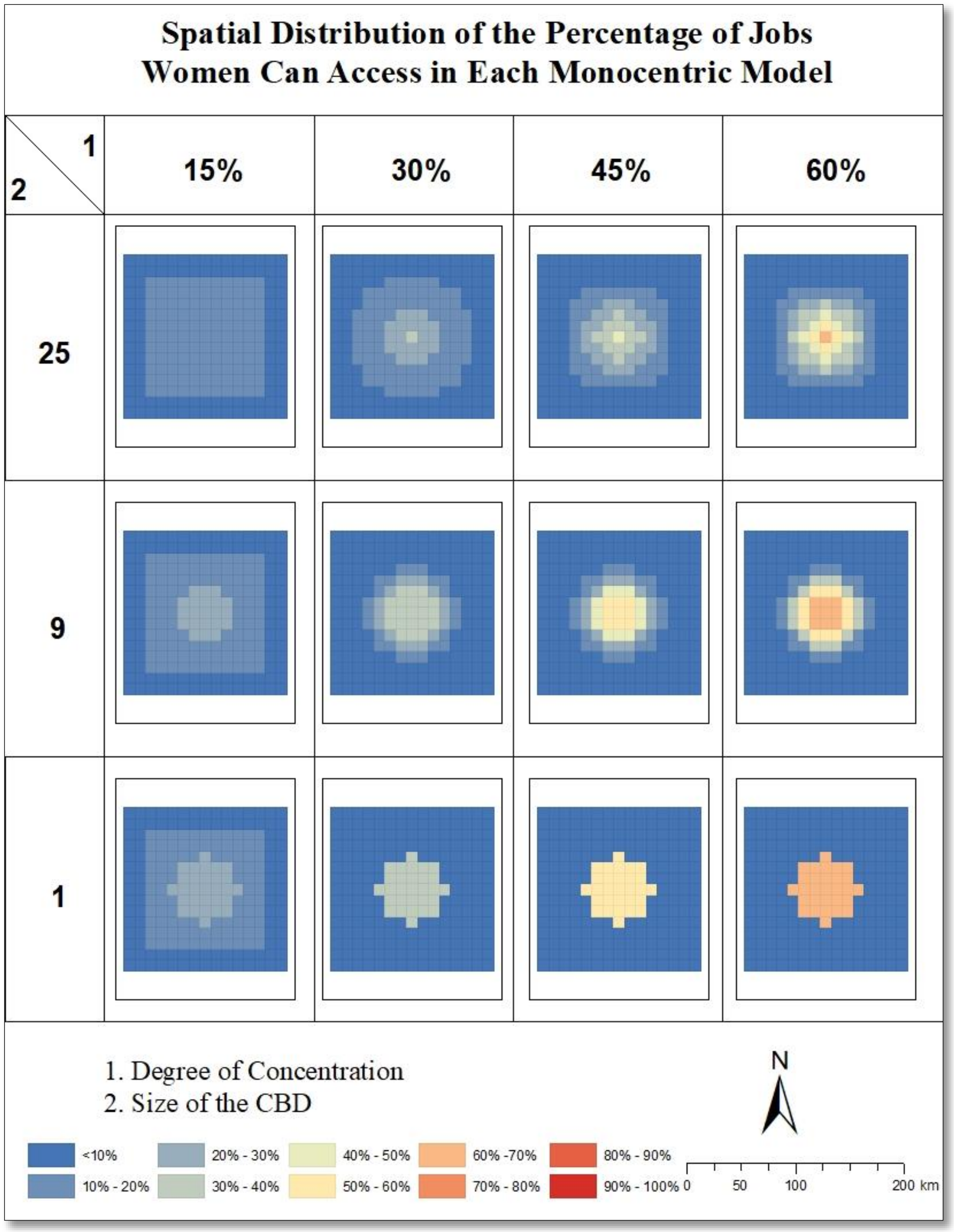


Figure 4.4 Spatial distribution of women's accessibilities in each monocentric model

Despite the similarity in the overall distribution patterns, the accessibilities in different parts of the cities vary from model to model depending on the different settings of degree of concentration and size of the CBD. To portray how accessibilities change from the innermost center of the city to the peripheral area, the accessibility values for grids located along the line starting from the innermost grid to the outermost grid at the straight north direction are used to produce a line chart for each model (shown in Figure 4.5). In each line chart, the x axis is the distance of the centroid of each grid to the centroid of the innermost grid of the city, while the y axis is the percentage of jobs individuals can access at the corresponding location. The spatial distribution of the accessibilities presents a perfect point symmetric pattern around the city center in each model. The accessibility values are equal for grids located at the same distance from the city center. Therefore, the change of the accessibility values along the selected direction serves as a good representative to depict the pattern of accessibility changes in the model. Three major patterns are detected from the line charts.

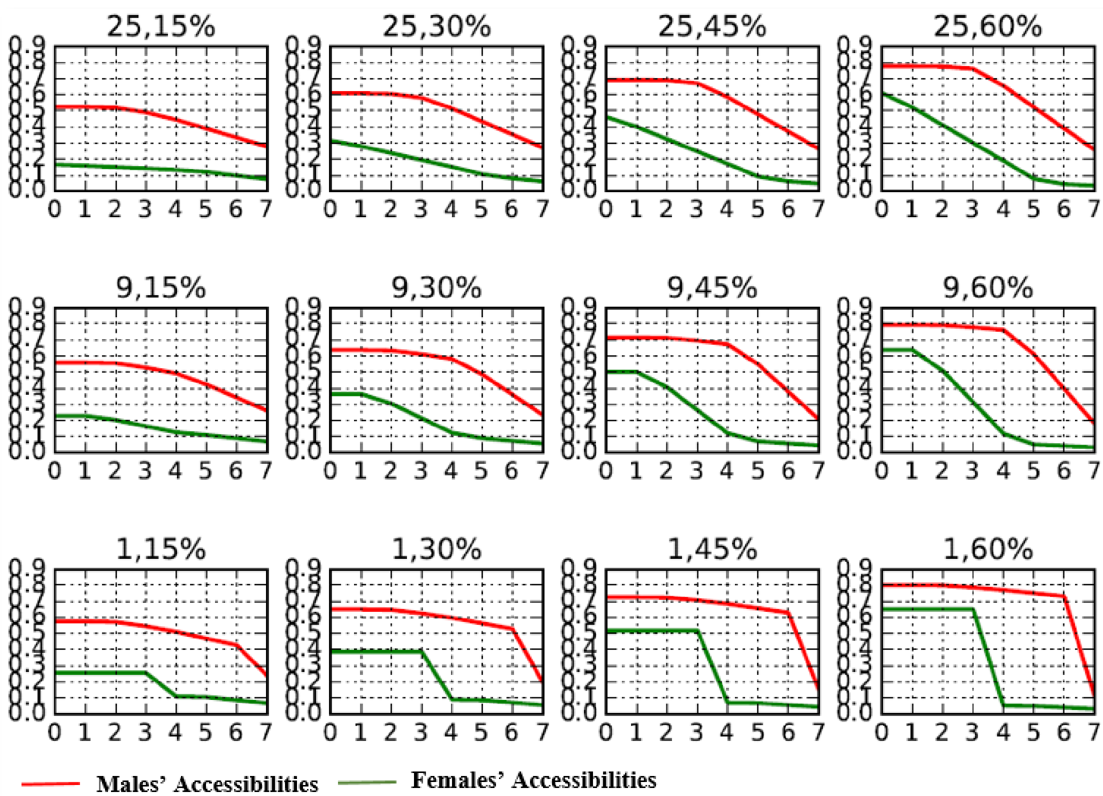


Figure 4.5 Change of the accessibilities from the center to the edge of each monocentric model

First, the line charts indicate that men's accessibilities at the center of the models are positively related to the degree of concentration values, but are not significantly influenced by the change in the CBD size. For example, in the models with CBD as one grid, when the degree of concentration values increase from 15% to 60%, the percentage of jobs men are able to access at the innermost grid (when x=0 in the line charts) grows from 52% to 80%. However, this number merely declines from 80% to 78% when the size of the CBD expands from one grid to 25 grids in models with 60% of degree of concentration. The strong relationship between the accessibility at the center and the degree of concentration is mainly because men living at or close to the center are able to access all jobs in the CBD. When the degree of concentration increases, larger proportion of jobs are included in the CBD, hence these men are able to access more jobs. As for the relatively weak influence of the CBD size on the accessibility at the center of the models, it can be explained by the following reasons. Men living at or close to the center cannot only access the CBD but also grids that are outside the CBD. The constant time budget for traveling to work determines that the job search area is identical for men in different models. Therefore, in models with larger CBD sizes, men will access less number of grids outside the CBD area. However, since the job density in grids outside the CBD is much lower than the job density in the CBD, the increase in the size of the CBD will only lead to a slight decline in the accessibilities at the center of the city.

The same relationship between the accessibilities at the center and the degree of concentration that has been detected for men is also found from women's line charts. When the degree of concentration increases, the accessibilities at the innermost center for women also become higher. However, the different degrees of concentration lead to the accessibilities for women at the center varying significantly higher by models. For example, in models with one grid as the CBD, when the degree of concentration values are 15%, 30%, 45% and 60% respectively, men's accessibilities at the innermost grid are 58%, 65%, 72% and 80%, which correspond to the increasing rates of 12%, 11% and 11% respectively. However, women's accessibilities at the same location are 26%, 39%, 52% and 65%. In this case, the increasing rates are 50%, 33%, and 25%, which are higher than men. Such a gendered accessibility pattern is also caused by the varying commuting time budgets between men and women. The shorter commuting time budget for women leads their job accessibilities to be more sensitive to the job density changes, hence the increase in the degree of concentration has greater influence on their accessibilities at the center.

The second pattern illustrated by the line charts is the difference in job accessibilities at the edge of the city among the models. According to the line charts, men in models with higher degree of concentration tend to have smaller accessibilities at the peripheral area. However, such disparities tend to be reduced when the size of the CBD expands. For example, in the models with one grid as the CBD, when the degree of concentration increases from 15% to 60%, the accessibilities for men at the edge (when x= 7) declines by approximately 10 percent points (from 25% to 15%). However, when the CBD size expands to 25 grids, this gap in accessing jobs at the edge of the city becomes only 3 percent points. This is mainly due to men at the edge of the city being not able to reach the CBD given their time budget for traveling to work and the size of the model. Besides, the increase in the degree of concentration indicates a reduction in the job density in areas outside the CBD. Therefore, the number of jobs men can access at the edge will decline when the degree of concentration climbs up. However, as aforementioned, when the size of the CBD expands, the job density in grids outside the CBD will increase. Therefore, in the models with a larger size of CBD, the degree of decreased accessibility at the edge of the model will be less than in models with a smaller CBD as the degree of concentration increases.

The influence of the degree of concentration and the size of the CBD on the accessibilities at the edge of the city for women is also similar to that for men. When the degree of concentration increases, the accessibilities at the edge decrease. The shrink in the size of the CBD will enlarge such gaps. The model with a 15% degree of concentration and 25 grids as the CBD size has the highest accessibility at the edge, and the one with 60% of degree of concentration and one grid as CBD size has the lowest accessibility at the edge of the models.

Last but not the least, the accessibility patterns at areas between the center and periphery are also different among the models. Specifically, the changes in degree of concentration and CBD size alter the way in which the accessibility values decrease from the center to the periphery of the city. As suggested by men's line charts, the decline of job accessibilities is not at a constant speed from the center to the edge of the model. The accessibilities remain the highest in areas that surrounds the center of the city. This is mainly because men can still access all the jobs in the CBD in these areas (which will be called the 'high-accessibility area' in the following parts of the chapter). The accessibilities do not drop significantly until the locations are at certain distances away from the center of the model where men are no longer able to access (all) the jobs in the CBD. Therefore, each line chart contains a turning point, the location at which the accessibilities start to plummet.

A closer observation of the line charts reveals that the turning points are different among the models in two aspects. First, the turning points are more obvious in models with a higher degree of concentration and a smaller CBD size. This is mainly because of the larger accessibility disparities between the center and the edge of the model, which leads to a sharper turning angle at the turning point where the accessibilities shift from the highest values to the lowest values. Secondly, the location of the turning point tends to be further from the center of the model when the CBD size becomes smaller. For example, in the models with a 60% of degree of concentration, when the size of the CBD reduces from 25 grids to 1 grid, the distance of the turning point to the center rises from 3 to 6 grids. As aforementioned, the locations within the boundary of the turning points are the 'high-accessibility area', where men can access equally high number of jobs with those at the innermost center of the model. Therefore, the further the turning point is from the center, the larger the areas in which men are able to gain the highest accessibilities.

Figure 4.6 demonstrates how the areas where men are able to access the full extent of the CBD vary by CBD size. In the models with a larger CBD, men need to live closer to the innermost grid of the models, so all the grids in the CBD can be completely covered in the spatial extent of men's job search area given their time budget for commuting. On the contrary, a model with a small CBD allows more men to be able to access the CBD. As demonstrated by the figure, the one with one grid as the CBD has the largest area in accessing the CBD, while the smallest area is found in the model with 25 grids as the CBD.

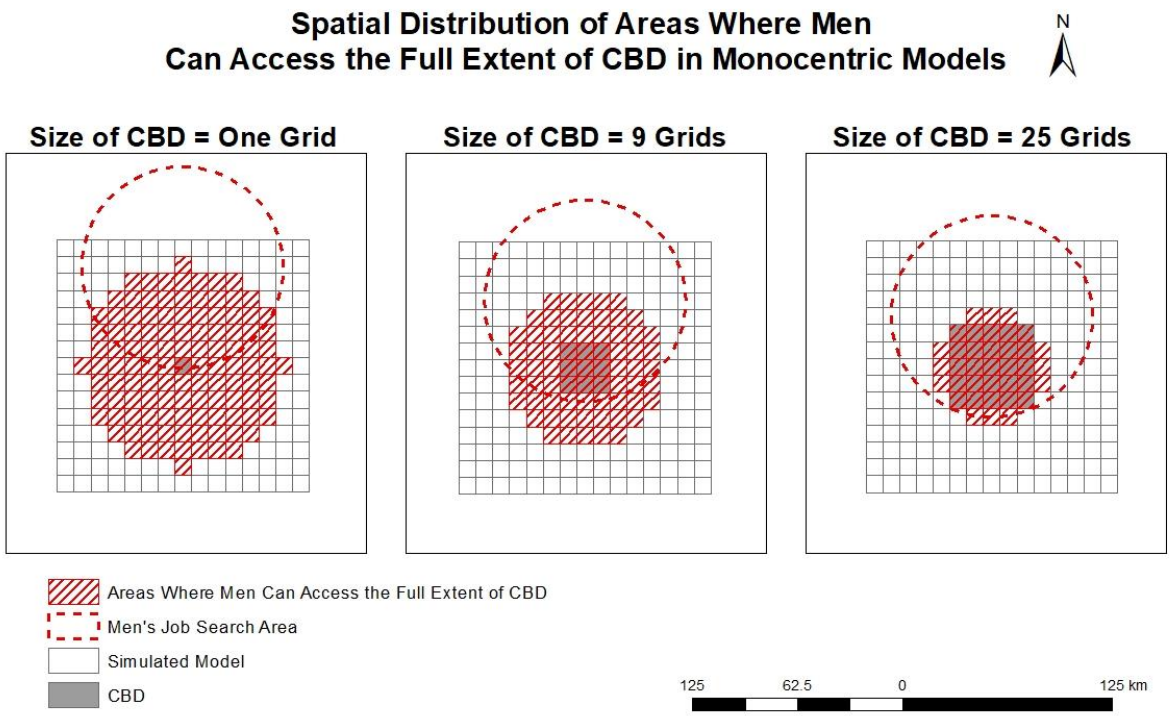


Figure 4.6 Spatial distribution of locations where men can access the full extent of the CBD in each monocentric model

Turning points are also shown on the line charts for women, which are located at grids surrounding the innermost center. Similar to the trend of men, the turning point becomes further from the center when the size of the CBD becomes smaller. However, since women have lower time budget for traveling to work, they need to be closer to the center to access the full extent of the CBD. Therefore, the turning points are more proximate to the center for women than for men on the line charts.

Besides the turning point described above, a second turning point is also detected on each line chart for women. The second turning point is located close to the city fringe, which indicates the range outside which women are not able to access any jobs in the CBD and gain the lowest accessibilities in the model (which can be called the 'low-accessibility area'). The location of the second turning point is also determined by the size of the CBD in the model. In models with a larger size of CBD, the chance for women who live far from the center to access the CBD jobs becomes larger. Figure 4.7 also demonstrates the locations where women are not able to access the CBD in models with different CBD sizes. As suggested by the figure, when the size of the CBD is 25 grids, the model has the smallest 'low-accessibility area' and hence the furthest distance of the turning point from the innermost center of the grids.

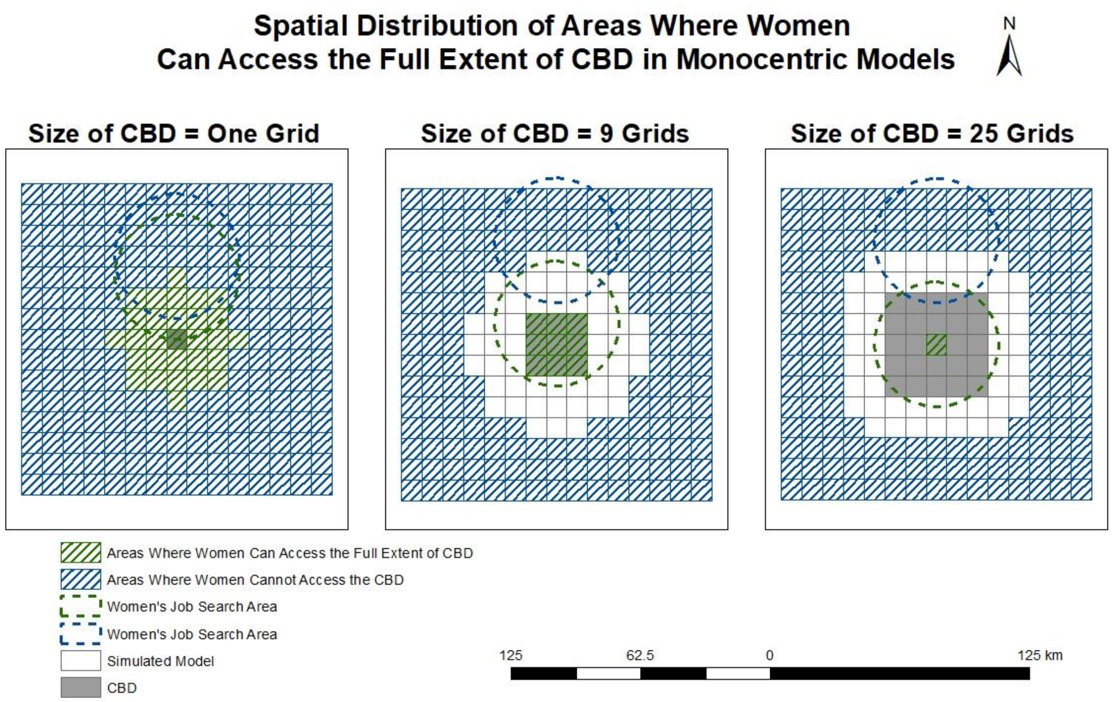


Figure 4.7 Spatial distribution of locations where women can access the full extent of the CBD in monocentric models

4.2.2 Gender disparities in accessing jobs in monocentric models

The spatial distribution of the ratio of women's job accessibility to men's job accessibility at each location in the monocentric models is shown in Figure 4.8. The maps indicate that the general patterns of the accessibility ratio between men and women are not 'monocentric', which is different from the distribution of job accessibilities for men and women. In the maps, the highest ratios are located at and around the innermost center of the city, indicating that men and women have the most equal accessibilities to jobs at the center of the city. As the locations become farther from the CBD, the gender equity decreases. However, when it reaches to the locations that are close to the edge of the city, the gender equity slightly increases. Therefore, the lowest gender equity in accessing jobs is not located at the edge of the models, where both men and women have the lowest accessibilities to jobs. Instead, the lowest gender equity is located at areas in between the center and the edge of the city.

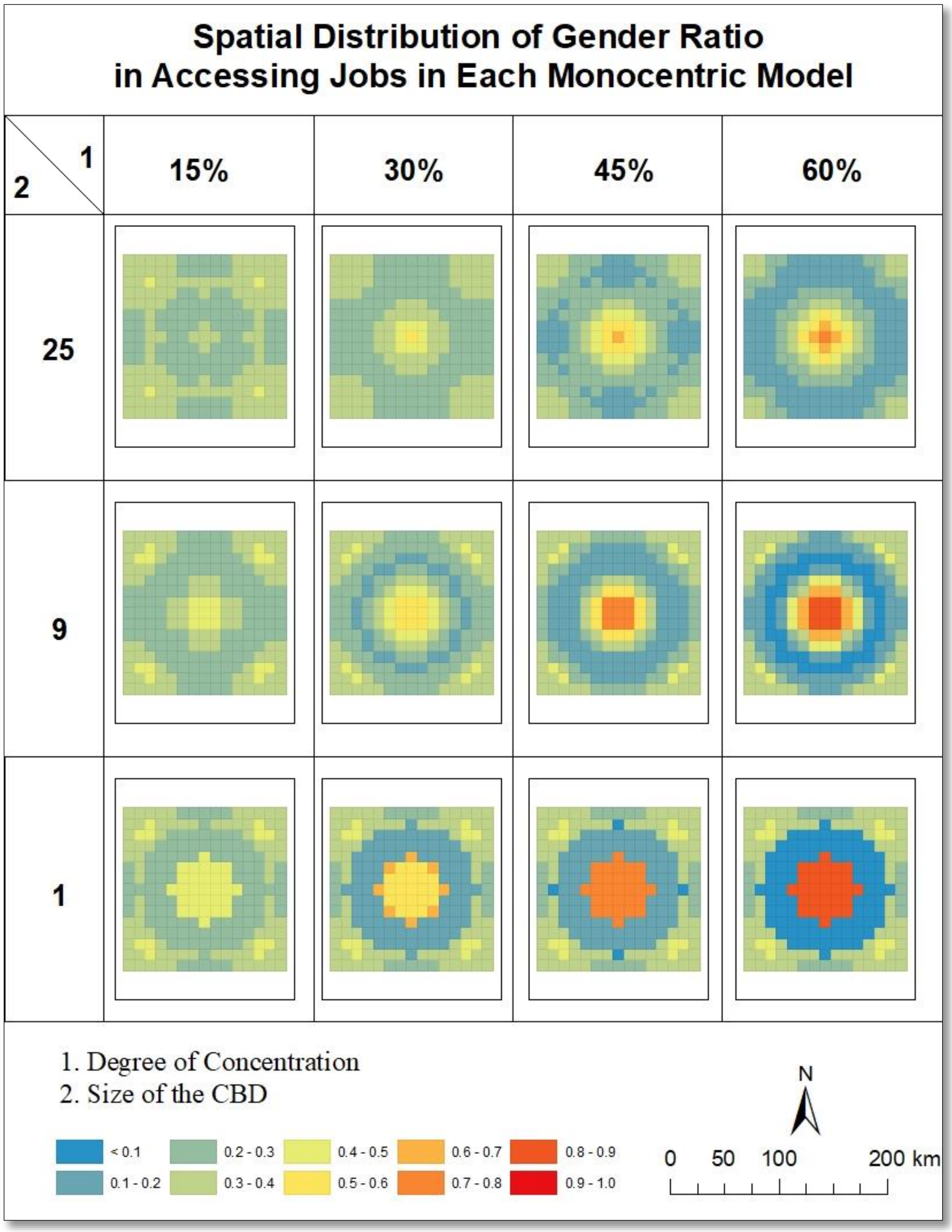


Figure 4.8 Spatial distribution of gender ratio in accessing jobs in each monocentric model

The spatial distribution patterns of gender difference in accessing jobs can be explained by the line charts shown in Figure 4.4. Both gender groups have 'high-accessibility areas' located in and around the CBD area in the city, in which they are able to access the highest amount of jobs among the other locations of the city. However, the boundaries of women's 'high-accessibility areas' are closer to the CBD than the boundaries of men's. Therefore, the gender equity is the highest at locations where men and women's 'high-accessibility areas' overlap. For locations being away from the CBD to a certain distance, women's accessibilities begin falling but men's remain the highest. Hence the gender equity starts to decline at these locations. For locations further away, the gender equity keeps decreasing. When it reaches to the locations where men's accessibilities also start declining, the gender equity begins to increase.

Regarding the influence of the degree of concentration and CBD size on local gender accessibility ratio, it is similar to the influence of these two factors on men and women's job accessibilities at local level in many aspects (which can be analyzed based on the line charts in Figure 4.9). First, the gender ratio at the innermost grid of the model is significantly related with the model's degree of concentration. When the degree of concentration increases, the gender ratio at the center also increases. The expansion in the CBD size will decrease the gender ratio, but only to a limited extent. In this case, the gender equity at the center is the highest in model with a 60% degree of concentration and one grid as the CBD, and it is the lowest in model with a 15% of degree of concentration and 25 grids as the CBD. Secondly, the low gender ratios which are located between the center and the edge is negatively associated with the degree of concentration, but positively correlated with the size of the CBD in the model. From the line charts, the lowest gender ratio in model with a 60% degree of concentration and one grid as the CBD is the smallest among the other models.

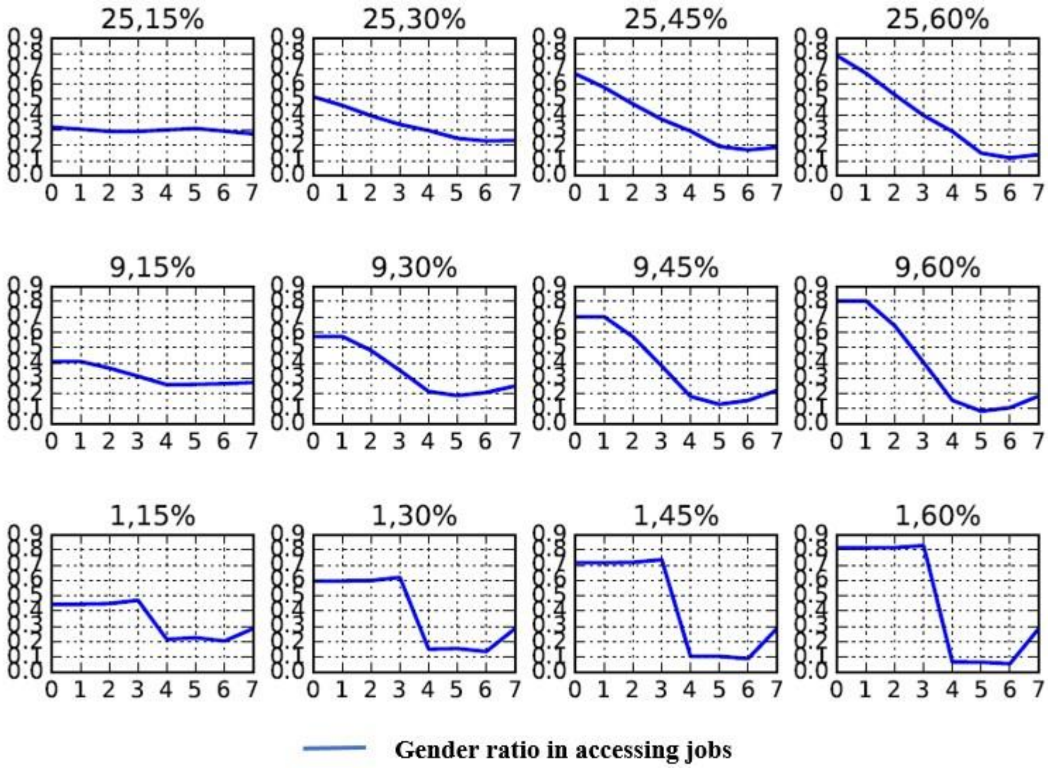


Figure 4.9 Change of gender ratio in job accessibilities from the center to the edge of each monocentric model

Similar to the 'high-accessibility area' for men and women, there is also a 'high-equity area' for gender accessibility ratio in each model. This area is distributed around the innermost grid. When the locations are outside the boundary of this area, the gender equity starts to fall towards the lowest values in the model. Therefore, a turning point is also shown in the line charts that reflects where the 'high-equity area' ends. Similar with the pattern found in men and women's line charts, models with higher degrees of concentration but smaller CBD sizes have more obvious turning points. Besides, the location of the turning point is also determined by the CBD size. It will be more distant from the center of the model when the size of the CBD becomes smaller.

In addition to the 'high-equity area', a 'low-equity area' is also detected in the line charts. It is located in between the beginning location of women's 'low-accessibility area' and the location where men's 'high-accessibility area' ends. From the line charts, the turning points to both the 'high-equity area' and the 'low-equity area' are more obvious for models with smaller CBD sizes. This is because the transition from the highest to the lowest accessibilities for men and women is smoother in models with larger CBD sizes. Therefore, the gender ratio disparities among locations for these models are smaller than those with small CBD sizes.

4.2.3 Men's accessibility patterns in polycentric models

The spatial distribution of the percentage of jobs men can access in each polycentric model is presented in Figure 4.10. According to the figure, the overall distribution of employment accessibilities for men in polycentric models also demonstrate a monocentric pattern. Although the employment centers are discretely distributed across the city, the highest accessibilities still cluster at and around the center of the city. This is mainly because of men's time budget for traveling to work allows those who live around the centers to access the jobs in all three employment centers, and hence to form the single 'center' of the job accessibility distributions for men.

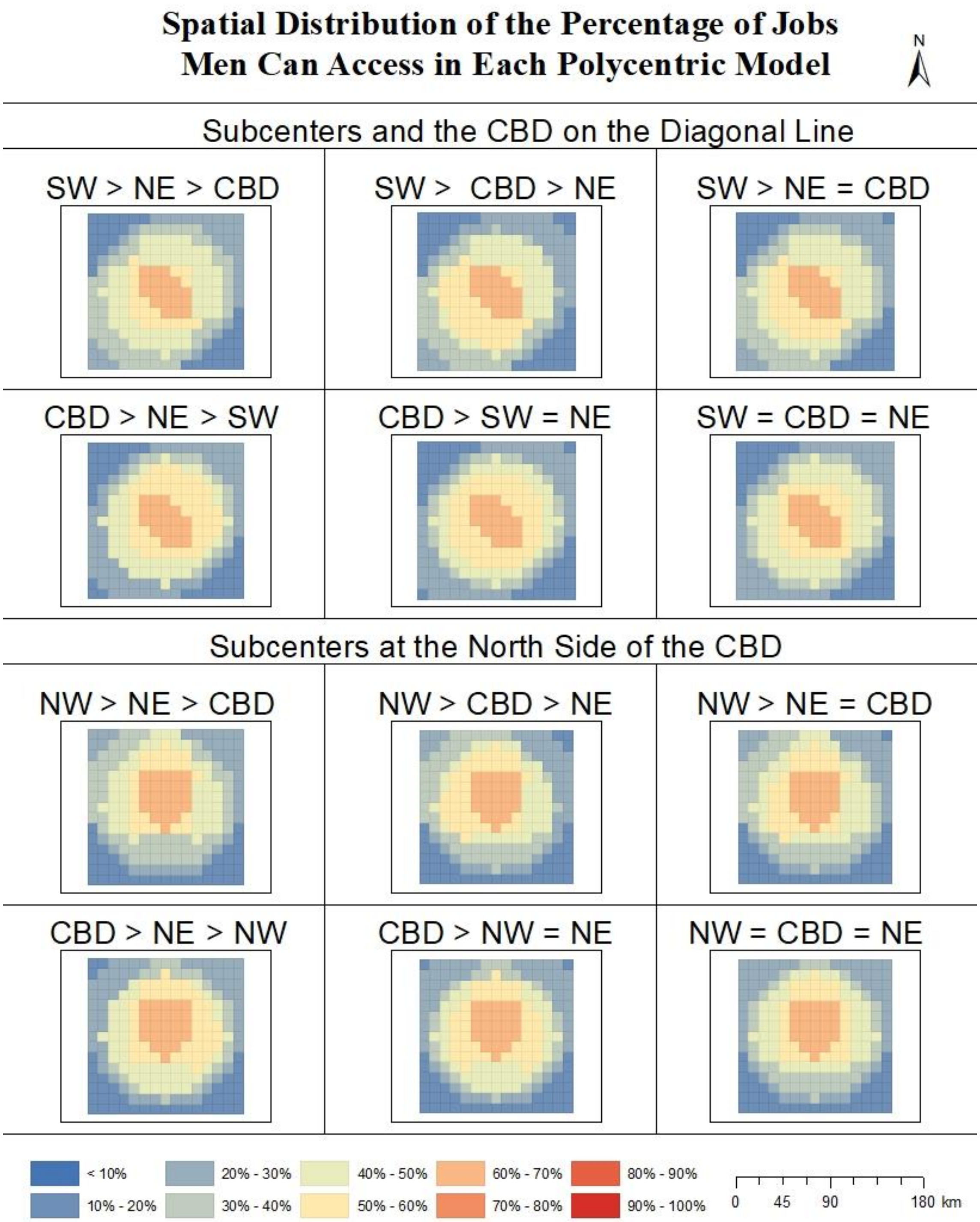


Figure 4.10 Spatial distribution of men’s accessibilities in each polycentric model

As aforementioned, two factors associated with the spatial distribution of jobs have been integrated into the polycentric modeling, including the locations of the centers and the amount of jobs at each center. They influence the accessibility patterns of men in different ways. According to the maps, the change in the locations of the centers mainly alters the skewness and symmetry of the general distribution of men's accessibilities. In monocentric models, the distributions of accessibilities for individuals in all monocentric models are a perfect point symmetry about the innermost grid of the models. Individuals living at the same distance from the center access identical number of jobs. However, in the polycentric models, since the locations of the centers are either inclined to one side of the model or scattered along the diagonal line, the distribution patterns of job accessibilities for men no longer exhibit point symmetry. When the centers are located at the SW-NE diagonal line of the grids, the highest accessibilities are around the center but perpendicular to the SW-NE diagonal line, and the lowest accessibilities are located at the Northwest and Southeast corners. When the two subcenters are located at the north side of the CBD, the highest accessibility values are skewed to the north and the lowest accessibilities are mainly distributed at the south of the city.

While the location shift of the centers alters the overall distribution patterns of men's job accessibilities, the change in the amount of jobs distributed at each center mainly influences the accessibility patterns at a local level. As aforementioned, the jobs in the three employment centers accounts for 30% of total employment in the city, and it is consistent across all the polycentric models. Therefore, when the locations of the centers remain identical, the change in how those 30% of jobs are distributed among the three centers will not change the accessibilities of men living at locations which allow them to reach all the three centers. Besides, there are also men who are not able to access any of the centers. The change in the amount of jobs at each center will not have any influence in the accessibilities of these individuals either. The distribution of the locations where men are able to access three or zero center(s) are shown in Figure 4.11. In locations where men are able to reach one or two center(s), the job accessibilities are sensitive to the job distribution change among the three centers. When men are living at places that they are able to reach center(s) containing larger proportions of jobs, their accessibilities tend to be higher than those who are only able to reach the center(s) with lower amount of jobs.

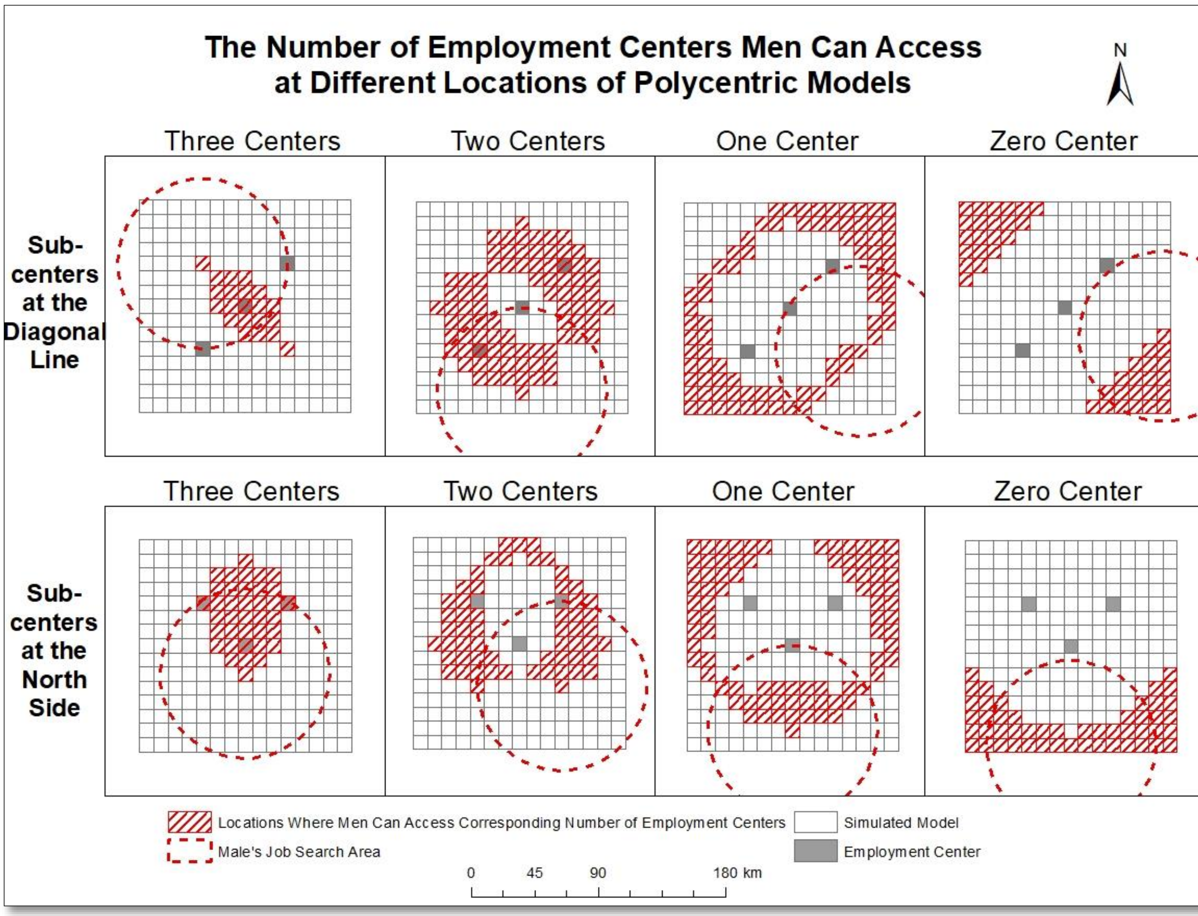


Figure 4.11 Number of employment centers men can access at different locations of polycentric models

4.2.4 Women's accessibility patterns in polycentric models

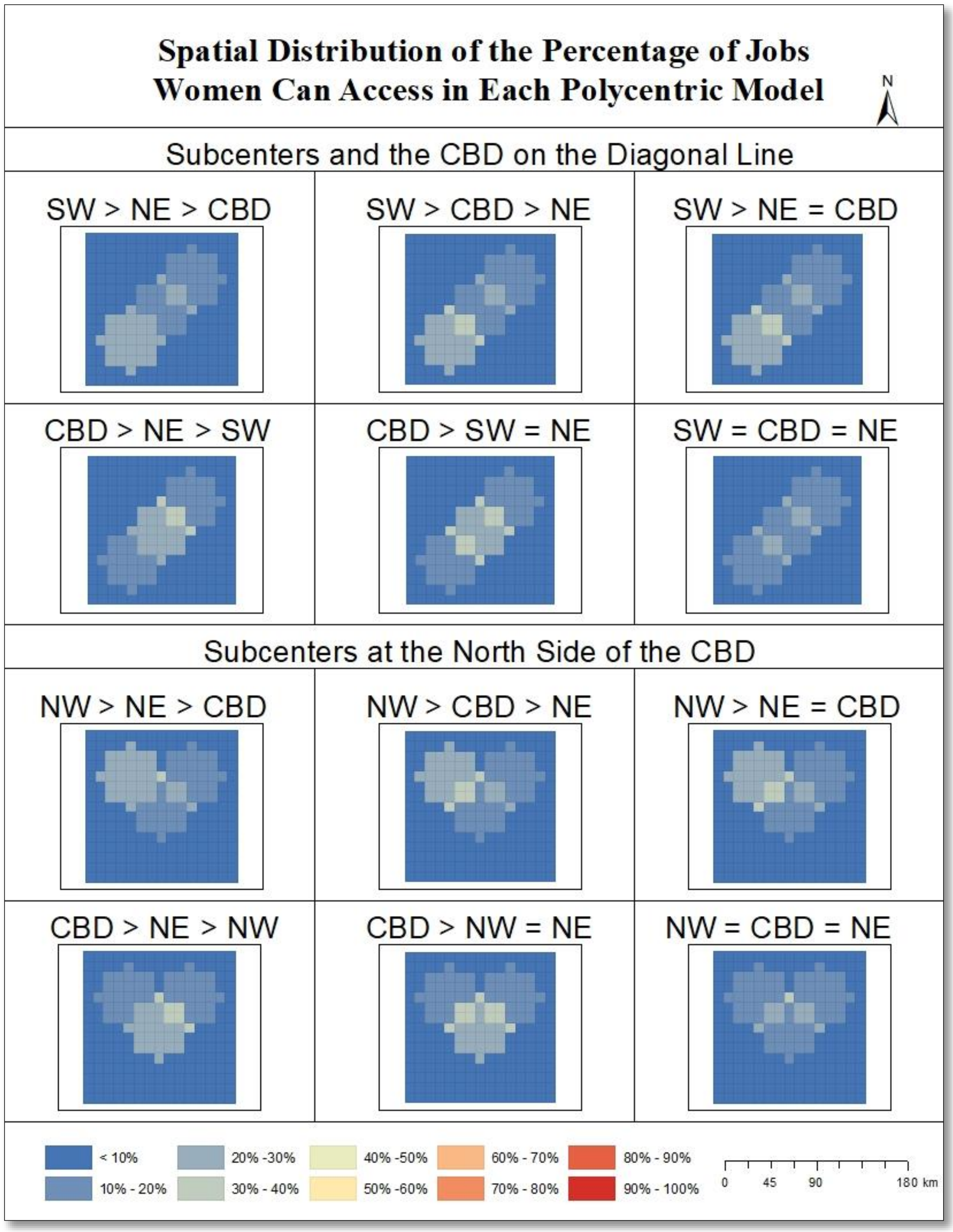


Figure 4.12 Spatial distribution of women's accessibilities in each polycentric model

Figure 4.12 demonstrates the spatial distribution of job accessibility for women in the polycentric models. According to the maps, the general distribution patterns of women's accessibilities are greatly different from men's. First, as suggested by the bluer color, the number of jobs women are able to access is significantly lower than men living at the same location of the city. Secondly, while the overall distribution pattern of accessibility for men demonstrate a monocentric character in all polycentric models, women's overall accessibility patterns present two different forms. When the subcenters are at the north side of the CBD, the accessibility patterns for women demonstrate a monocentric character. The grid located between the three employment centers has the highest accessibility in the model. For locations away from the grid, the accessibilities decrease monotonically (although at varied speed in different directions). However, when the subcenters are located along the SW-NE diagonal line, the accessibility distributions for women tend to present polycentric patterns. No obvious single 'center' is detected. Instead, the high accessibilities are distributed at discrete locations which become the multiple 'centers' of the accessibility distributions.

The different types of accessibility distributions for women are the integrated effect of women's time budget for traveling to work and the distribution patterns of jobs of the polycentric models. Women's more limited time budget leads to a smaller job search area. When the subcenters are located along the SW-NE diagonal line with the CBD, the distances among the three centers are much longer than those when the subcenters are located at the north size of the CBD. Therefore, it is impossible for women to access the jobs in all three centers at any grid in models where the centers are located along the diagonal line. The highest accessibilities are obtained at locations where women can reach two of the centers, which are not contiguously distributed in space. However, when the centers are located at the north side of the CBD, the shorter distances among of the centers allow women living at one grid of the model to access all the three centers. The general distribution of accessibilities becomes monocentric, and this grid can be considered as the "center" of the distribution.

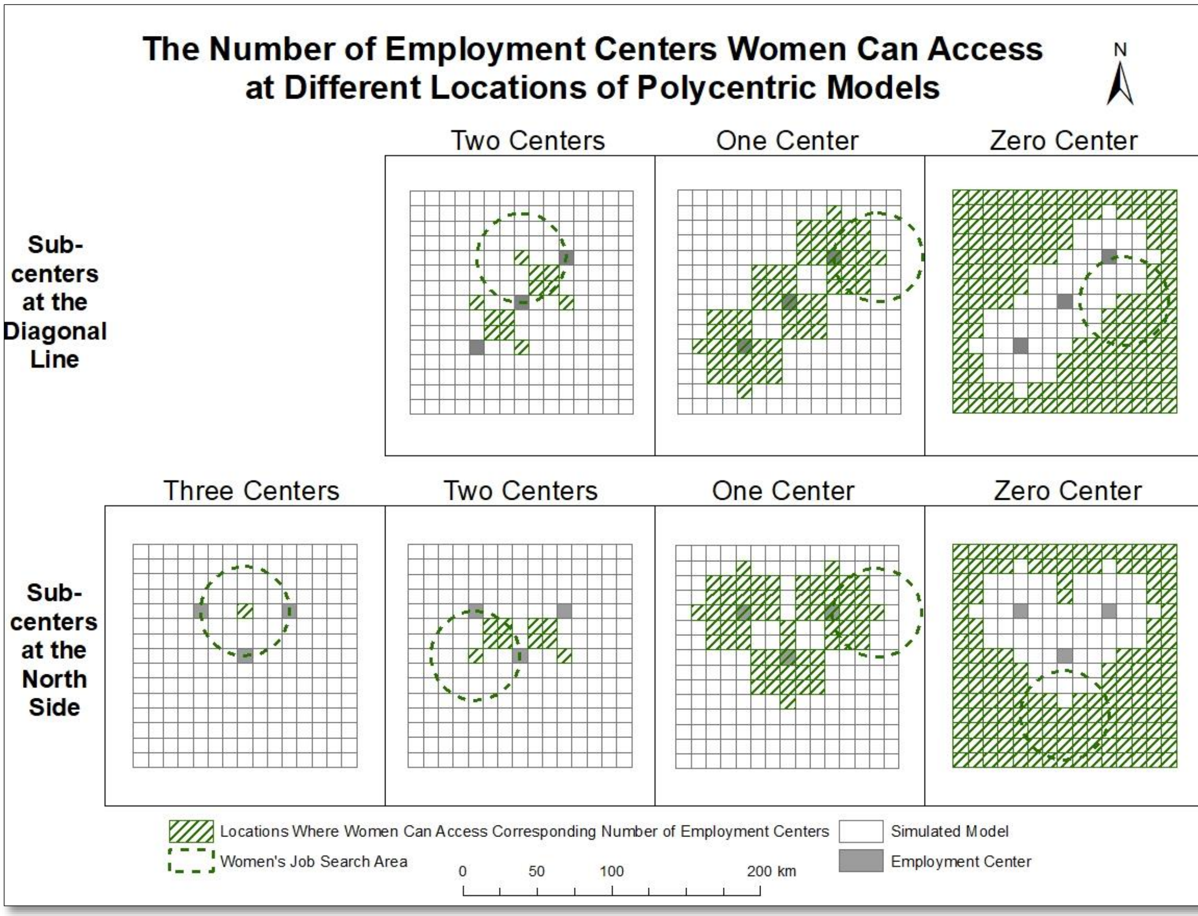


Figure 4.13 Number of employment centers women can access at different locations of polycentric models

Similar to men's accessibility patterns, the amount of jobs distributed at each center also affects women's accessibilities at the local level The change in job distribution among the centers does not alter the accessibilities of women who are not able to reach any of the centers. However, due to women's shorter commuting time budget, the areas where women are not able to access any of the centers are much larger than men's (shown in figure 4.13). The job distribution among the centers will only influence the accessibilities of those who are able to access one or two centers. These locations are tightly bounded to be around the centers. They cover much smaller areas than those for men's, because of women's smaller time budget for traveling to work.

4.2.5 Gender disparities in accessing jobs in polycentric models

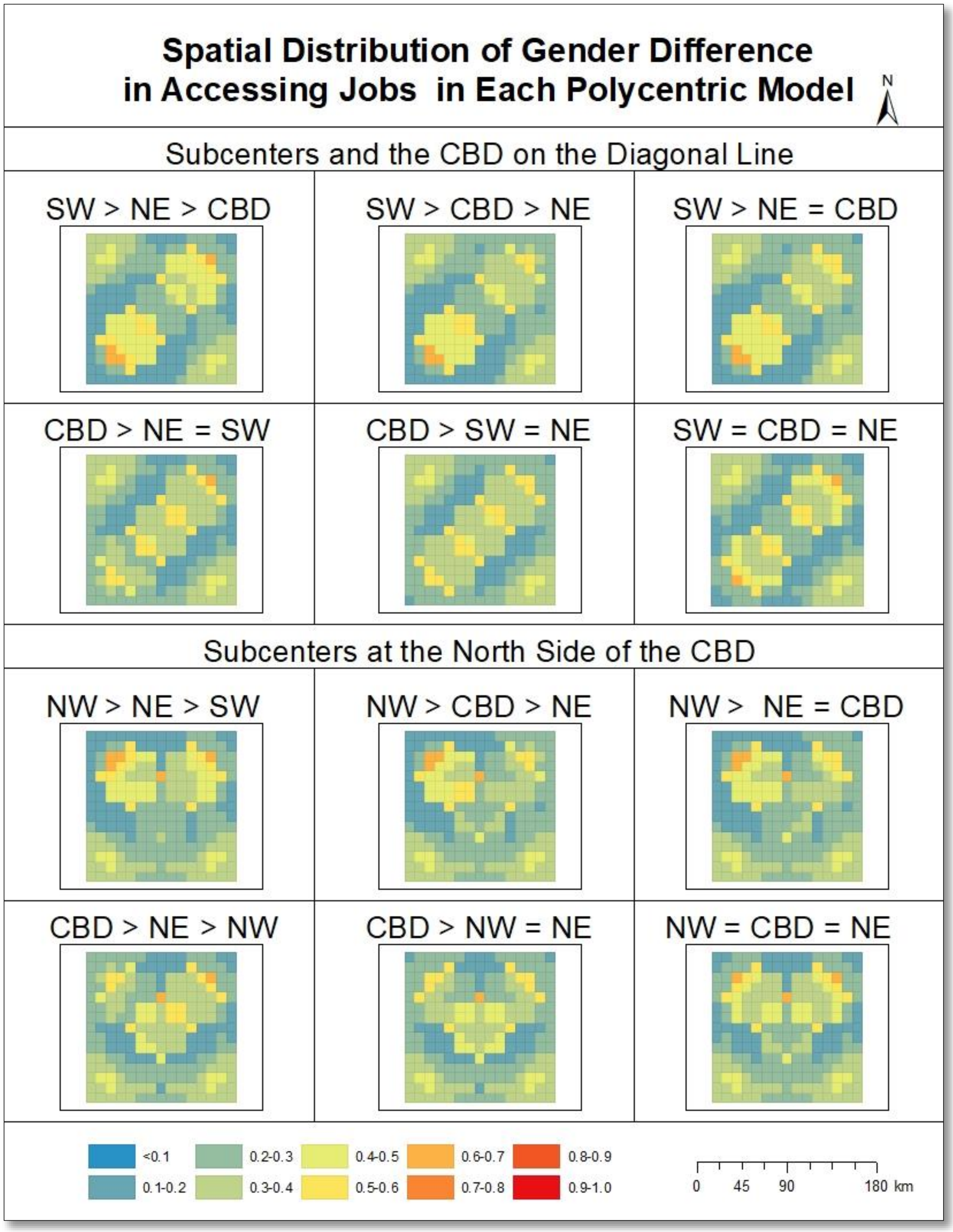


Figure 4.14 Spatial distribution of gender ratio in accessing jobs in each polycentric model

Figure 4.14 demonstrates the spatial distribution of the gender ratio in accessing jobs in each polycentric model, which is complicated than the patterns in the monocentric models. The high and low ratios scatter at different locations in the models rather than the similar values clustered in space.

The highest gender equity is located at grids that women obtain the highest accessibilities but men can only access medium number of jobs among the other. Similarly, the lowest gender equity in each polycentric model is not distributed at locations where both gender groups access the smallest proportion of jobs but where women have the lowest accessibilities while men do not.

According to the above analysis, the distribution of the gender ratio in accessing jobs should be highly related with the locations of the employment centers. Since the higher ratios are obtained at locations where women can access the highest amount of jobs in the model while men cannot, they tend to be distributed around the subcenters (where women are able to access two centers) but not too close to the traditional CBD (where men are able to reach all the three centers). Besides, the amount of jobs distributed in each center also influence men and women's job accessibilities at certain locations. In this case, men and women tend to have more equal accessibilities around the subcenters that have higher job density than the others. Also, as aforementioned, the lower gender equities are found at locations where women's accessibilities are the lowest in the model while men's are not. Therefore, these values usually distributed at the outer circles of the highest gender equities, where women are not able to access any of the center while men are still able to reach one of them.

4.2.6 Summary and discussion

This chapter analyzed the job accessibility patterns of men and women in two typical urban forms given their different time budgets for traveling to work. The analysis finds both similarities and differences between men and women's accessibility patterns in various models, which reflect the integrated effect of the spatial distribution of jobs and gendered time budgets for commuting.

Women's accessibility patterns are similar with men's in many aspects. In monocentric models, the general distribution of men and women's accessibilities both demonstrate a monocentric character, as individuals living closer to the center always have larger job accessibilities than those living further from the center of the model. Besides, the association between the accessibilities at different parts of the models and the two job distribution factors (including the degree of concentration and the CBD size) are the same for both gender groups. The growth in the degree of concentration and the shrinkage in CBD size will lead to the ascent of accessibilities for individuals residing at the center of the city, but the descent of accessibilities for those living at the edge. As a result, the accessibility disparities between the center and the edge of the model also increases. In addition, the decline in CBD size will increase the size of the 'high-accessibility area' both men and women. In polycentric models, the shift in the locations of the three employment centers and the amount of jobs distributed in each center will change the distribution of higher and lower accessibilities for both gender groups. These common patterns men and women share reflect the influence of the spatial distribution of jobs on individuals' accessibilities to a great extent.

However, the research also finds pattern differences between men and women. In monocentric models, the gender accessibility variation is mainly reflected in two aspects. First, as the degree of concentration grows, the extent of increase of accessibility at the center is larger for women than men. Secondly, the 'high-accessibility area' for women is smaller in each model, and a 'low-accessibility area' is found for women but not detected in men's patterns. In polycentric models, the general distributions of accessibilities show different patterns between men and women. Men's accessibilities still demonstrate monocentric patterns. The larger commuting time budget grants the access to all three employment centers for men dwelling in grids that are clustered around the city center. For women, in models where the three centers are closely distributed with each other, the distribution patterns of accessibilities also show a monocentric character. However, given women's smaller time budget for commuting, the 'center' of the distribution is much smaller than men's. There is only one grid that allows women to access all the three employment centers. In models where the centers are distributed farther apart, women are unable to access all three centers at any location. In this case, the accessibility distributions for women demonstrate polycentric patterns. However, the lowest gender equity is also found at the periphery in the same model.

The varying accessibility distributions between men and women results in uneven spatial distribution of gender ratio in accessing jobs. The job distribution factors also significantly influence how the gender accessibility ratios are distributed in different models. A model with a highly concentrated job distribution offers people residing in the center high gender equity in accessing jobs. However, it will also lead the residents in the periphery to have extremely disadvantageous equity in gender accessibility. In contrast, when jobs are distributed more evenly across the space, the individuals living around the center of these models are unable to enjoy an equally high gender equity in accessing jobs. Fortunately, the gender accessibility disparities at the edge are also reduced. While it is not easy to determine which types of models would provide higher gender accessibility equities for the residents, further efforts are needed to help compare the gender equities among different models at the city level.

Delafontaine et al. (2011) conducted a study focusing on the equity of individual's space-time accessibility to public service facilities under different opening hour strategies. In this research, the authors summarized various equity principles, among which two will be utilized in this study to evaluate the overall gender equity in job accessibilities for the models. One principle is named 'Utilitarian', which refers to the regime that will maximize the overall gender equity across the population. The other is the 'Egalitarian' strategy which aims to minimize the disparities in gender equity among the individuals in the region. These two principles represent different aspects of equity. In this chapter, the mean and the standard deviation of the gender ratio in accessing jobs is calculated for evaluating the overall equity and the disparities among different locations for each model.

Table 4.2 Mean and standard deviation of gender ratio in accessing jobs for each model

	Size of the CBD	Degree of Concentration	Mean	Standard Deviation
Monocentric	1	**15%**	0.310	0.083
		30%	0.304	0.146
		45%	0.301	0.197
		60%	0.299	0.237
	9	**15%**	0.309	0.049
		30%	0.293	0.098
		45%	0.278	0.143
		60%	0.263	0.181
	25	**15%**	0.316	0.034
		30%	0.295	0.053
		45%	0.272	0.091
		60%	0.247	0.126
	Subcenter Location	**Relations among Centers**	**Mean**	**Standard Deviation**
Polycentric	Diagonal	**SW>NE>Center**	0.306	0.126
		SW>Center>NE	0.302	0.114
		SW>NE=Center	0.304	0.119
		Center>NE>SW	0.299	0.107
		Center>SW=NE	0.299	0.106
		SW=CBD=NE	0.302	0.112
	North Side	**NW>NE>Center**	0.305	0.116
		NW>Center>NE	0.302	0.108
		NW>NE=Center	0.303	0.111
		Center>NE>NW	0.299	0.103
		Center>NW=NE	0.299	0.102
		NW=Center=NE	0.303	0.105

Table 4.2 shows the results of the mean and standard deviation of gender ratio in accessing jobs in each model. According to the table, the highest mean and the lowest standard deviation value are both found in the monocentric model with a 15% degree of concentration and 25 grids as the CBD (referred to as M_25_15 in the following parts of the paper). It indicates that the overall gender equity in this model is the highest in terms of both utilitarian and egalitarian principles. M_25_15 model is the one with the largest CBD size and the lowest degree of concentration. Since this model has the

most dispersed job distribution among all the simulated models, this result may indicate that a more even distribution of jobs will help improve the overall gender equity for employment.

Additionally, the results show that the mean gender ratios in polycentric models do not show large variations among each other, and they are very close to the mean gender ratios in monocentric models with a 30% degree of concentration. This pattern may demonstrate the importance of the degree of concentration in influencing the overall accessibility patterns in terms of utilitarian principle compared with the other factors, as all these models have the same proportions of jobs distributed in the center(s). An ANOVA test is conducted to compare the mean gender ratio in accessing jobs among all the polycentric models and the monocentric models with 30% degree of concentration. The result of the ANOVA test shows there's no significant difference in the mean values among the models, which may suggest the overall gender equity in job accessibility at a metropolitan area is more sensitive to job concentration level in the employment centers than urban form.

The simulated urban models highlight how the changes in the number, size, and location of employment centers, as well as the job concentration level alter men and women's experience in accessing jobs in a city. It provides a comprehensive guidance on understanding the influence of the various job distribution factors on the gendered patterns of space-time accessibilities to job opportunities. Nevertheless, the models are created based on well-controlled forms, which are not able to fully reflect the complexity of urban form in a real-world city. Elements that are also expected to impose effects on individuals' job accessibilities have not been included in the simulated models. For example, few cities will have an even job density across the suburban area, and individuals rarely travel through straight distance. In the next chapter, a real city will be used as a case study to further explore the connection between the more complex urban form of an actual city and gender difference space-time accessibilities to jobs.

CHAPTER V

GENDER DIFFERENCE IN EMPLOYMENT ACCESSIBILITY IN CHICAGO METROPOLITAN AREA

The analysis on the well-controlled simulated city models offered a systematic investigation on how urban form and time budget for traveling to work affect the gender difference in accessing employment opportunities. A more concentrated urban center brings more employment opportunities to both men and women living close to the center, hence promotes a more leveled ground for men and women to compete for job opportunities. However, such an urban form also deepens the gender employment gaps for people living near the edge of the city. A more even distribution of jobs, such as in the multi-center urban forms, alleviates the extreme cases of gender gaps, but presents a more consistent disadvantage for women to access job opportunities across the city.

In the real world, a city rarely takes a clearly defined urban form as delineated in the simulated cities. The more complex spatial form of a real city leads to a more uneven distribution of jobs, which in turn affects gender difference in accessing jobs. Besides, in a real city workers commute through street networks instead of in straight lines as assumed in the simulated models. The uneven distribution of roads and the varying travel speeds on the roads further complicate the spatial patterns of the gender job accessibility gaps. In this chapter, a real city is used as a case study for a further investigation on gender employment opportunities difference to 1) demonstrate the usage of the methodological framework developed in chapter III with more complicated data from an actual city, and 2) understand the influence of the spatial distribution of jobs on men and women's job accessibilities and hence their experience in occupation participations in the city. Chicago Metropolitan Area (CMA) is selected as the study area. With data obtained from the Chicago Metropolitan Agency for Planning (CMAP) and the Census Bureau, the daily activity patterns of both gender groups will be examined first, followed by the analysis on the spatial distribution patterns of jobs in the overall employment and in different occupations. The job accessibility patterns of men and women in CMA will be then calculated with the time-geographic methodology framework developed in Chapter III. Finally, the overall gender difference in job accessibilities will be analyzed. Discussions on the connection among job distributions, space-time accessibilities, and occupational gender segregation will be provided in the end of this chapter.

5.1 Study Area and Data

5.1.1 Study area

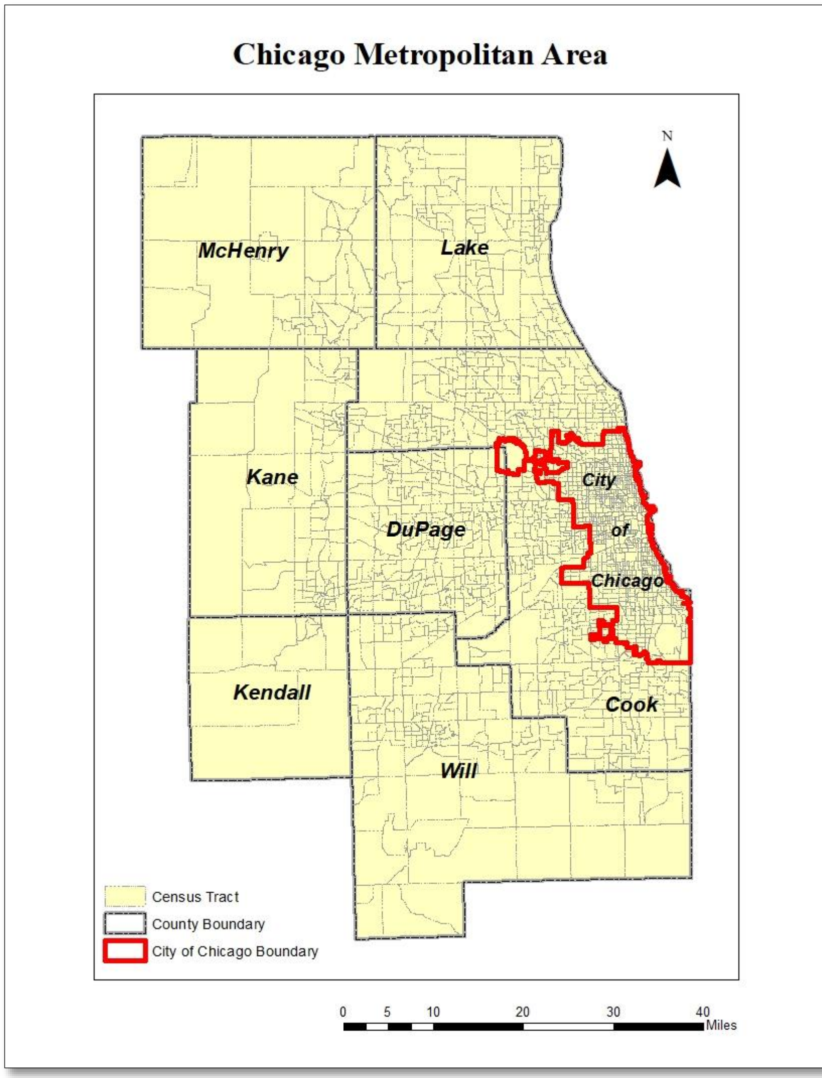


Figure 5.1 Spatial extent of CMA

The CMA (shown in Figure 5.1) spreads across seven counties in Illinois, including Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will County (definition based on CMAP). According to the United States Census Bureau (2010), the region covered 10,543.69 square kilometers of area, with a total population of 8.43 million, among which 48.89% are men while 51.11% are women. The city of Chicago, which is located in Cook County on the southwestern shore of Lake Michigan, functions as CMA's core city. It concentrates 31.9% of the total population and 31.2% total employment of the region.

The main reason for selecting CMA as the study area is due to the availability of disaggregated activity-based data for investigating the different levels of constraints on employment activities between men and women. The details of the data will be introduced in the next subsection. Like most of the large metropolitan areas in the U.S., CMA has experienced rapid population expansion and dispersion. During the period from 1970 to 2010, the total population has increased by 20.4%. However, most of the growth occurred in the suburbs, as indicated by a much higher population increasing rate of 57.6% outside the City of Chicago and a decreasing population rate of 19.9% within the City of Chicago. In the meanwhile, jobs are also decentralized from the inner city to the suburbs (Zhang, 2001; McMillen, 2001; McMillen & William Lester, 2003). The more dispersed distributions of residence and employment might have lengthened the commuting distances/time and caused inconvenience to workers in accessing jobs. Since women are more likely to have more limited commuting time budget due to their gender roles, the impact of population and job distribution on women's job accessibility might be more significant. Therefore, gender differences in accessing jobs in the study area are expected to be discovered in the study area. The results can inform the residents the comprehensive distributions of job accessibilities for men and women, and help them better understand where they are able to gain higher gender employment equity in the region.

5.1.2 Data

The investigation on gender gap in accessing employment opportunities will start with an analysis on the two factors that are associated with job accessibilities of men and women: the different household responsibilities between men and women, and the uneven spatial distribution patterns of jobs across the area. The analysis on each of the two factors requires distinct datasets, which will be introduced in this subsection. These datasets will also be utilized by the subsequent calculation on job accessibilities of men and women in this chapter.

An analysis focusing on individuals' daily activity patterns for men and women will be carried out to study the influence of household responsibilities on employment accessibility. This activity-pattern analysis relies on disaggregated data that demonstrates detailed activity information, such as the types of activities individuals engaging in and the time when the activities take place. Such data is extracted from the Travel Tracker Survey data, an activity-based, publicly available database collected by CMAP between 2007 and 2008 in eight counties (including all seven counties in the study area as well as Grundy County) in the Northeastern Illinois Region (CMAP Data Hub, 2016). The survey includes a total of 10,552 households in the eight-county area. These households participated in a 24-hour or 48-hour survey starting at 3:00 am, reporting information on every trip their members made in the assigned day(s), including the purpose, origin, destination, arrival time, departure time and travel mode of the trip as well as the number of people joined in the trip.

As a representative sample of the region's population, the data set includes respondents from all subpopulations with distinct demographic characters. Since this study focuses on individuals' employment-related patterns, respondents under 16 years old who are not allowed to work or above 65 years old who are usually retired are excluded. In addition, since most employment activities take place during weekdays, respondents who participate the survey on weekends are not included either. Finally, respondents residing in in Grundy County, which is not in the study area, are also excluded.

Therefore, a subsample including activity-travel information of 6,542 men and 7,391 women are extracted from the Travel Tracker Survey data for the exploration of the different household responsibilities between men and women in CMA.

The exploration of the spatial distribution patterns of employment opportunities in CMA involves an analysis of the region's urban form, as well as a comparison of the distribution patterns of jobs among various occupation groups. Such an exploration is based on a subdataset extracted from the CTPP 5-year Data Set (2006-2010). It is created by the Bureau of Transportation Statistics (BTS) based on the 2006-2010 5-year American Community Survey (ACS) data, mainly focusing on the journey to work characteristics of workers in the U.S (CTPP 5-year Data Set, 2006-2010). It contains detailed demographic information of workers (e.g. occupation, income, and household size) and their commuting patterns (e.g. travel mode and travel time). The information is summarized at different levels of geography, such as state, county, census tract, traffic analysis zone and so on. The CTPP 5-year package contains three parts. Part I and Part II offer residence-based and workplace-based information respectively, and Part III reports the commuting flows between residence and workplace. This chapter will mainly rely on data from Part II, which reports the total number of workers in various occupations by place of work at the census tract level. The data will be used for detecting the employment distribution patterns and evaluating the different job accessibilities for men and women.

5.2 Gender Difference in Household Activity Patterns

Gender roles have been found in many studies (e.g. Johnston-Anumonwo, 1992; Turner & Niemeier, 1997; Rapino & Cook, 2011; Fan, 2015) as a factor affecting equal job accessibility between men and women. These studies mainly utilize multivariate statistical methods, in which gender roles are modeled as variables associated with household structure, such as marriage status and parenthood. However, although the methods illustrate the relationship between gender roles and accessibilities, they have not been able to capture the mechanism on how gender roles limit women's job accessibilities. From the perspective of men and women's daily activity patterns, the new methodology framework developed in Chapter III offers a conceptual tool for understanding the mechanism on how gender roles impose time constraints on women's employment activities and lead to their more disadvantageous accessibilities to job opportunities. This section will use real data from Travel Tracker Survey to analyze men's and women's activity patterns in CMA based on the conceptual framework of the new methodology. The analysis will demonstrate whether women in the study area shoulder more gender roles and whether the roles affect their employment accessibility.

The analysis in this section is divided into three parts. The first part discusses the process of activity selection. The Travel Tracker Survey data reports all kinds of activities respondents performing during the survey day(s). Only those associating with household responsibilities will lead to different experience in accessing jobs between men and women, hence will be selected. The second part involves an analysis on the general patterns of the selected activities for men and women. It will demonstrate whether women in CMA are responsible for more household tasks. The third part focuses on investigating the time allocation patterns of the selected activities. It can help illustrate how men and women distribute the household activities in time dimension and how the distribution will influence their employment accessibilities.

5.2.1 Selection of activities

The respondents in the subsample from the Travel Tracker Survey report a total of 23 types of activities (shown in Table 5.1), which can be divided into the following classes: 1) subsistence activities which include work/school and work/school related activities, 2) maintenance activities which encompass household activities and activities that fulfill physiological and biological needs, and 3) leisure activities which comprise activities usually taken at free time to meet cultural and psychological needs. In addition, there is also a group of activities, of which the purposes have not been specified. These activities are categorized into other activity class, which will not be included in the following analysis.

As discussed in the conceptual framework in Chapter III, subsistence and maintenance activities are both indispensable, because they provide essential supports for individuals' daily lives. However, since the fulfillment of both activities takes a significant amount of time, individuals develop various strategies to cope with the time pressure brought by both activities. The most typical strategies are gendered, with the husbands mainly focusing on employment activities, while the wives shouldering more household responsibilities. In this case, the household-related activities have higher priority to employment activities for women but lower priority for men. The different priorities on employment activities and household-related activities between men and women lead to the variation on men's and women's time constraints on employment activities, hence the different accessibilities to employment activities.

Table 5.1 Categorization of activity classes in Travel Tracker Survey data

Major Activity Category	Detailed Activity Class
Subsistence Activities	Working at home (for pay), Work/Job, All other activities at work, Work/Business related, Attending class, All other activities at school;
Maintenance Activities	Dropped off passenger from car, Picked up passenger, Routine Shopping, Household errands, Shopping for major purposes, All other home activities, Health Care;
Leisure Activities	Eat meal outside of home, Civic/Religious Activities, Recreation/Entertainment, Visit Friends/Relatives;
Other Activities	Change type of transportation/transfer, Service Private Vehicle, Loop trip, Other Transportation, Personal Business, Other Activities

Therefore, this section will focus on analyzing the household-related activity patterns for men and women, aiming at understanding whether women shoulder more housework responsibilities and whether these responsibilities will impose more time constraints on women's employment activities.

Six types of activities in maintenance activity class are selected that are closely associated with household responsibilities, including all other home activities, drop off passenger, pick up passenger, routine shopping, shopping for major purposes, and household errands. Among them, shopping for major purposes activities account for a much smaller proportion than the other activities, hence will be combined into routine shopping activity type in the following analysis.

It is worth noting that the all other home activities refer to all kinds of activities that are conducted at home and have not been classified as any other defined activity types. It includes not only in-home household activities (e.g. cooking and house cleaning) but also in-home physiological and biological activities (e.g. sleeping and having meals at home), and leisure activities (e.g. watching television program or playing video games at home). However, since it is impossible to differentiate the in-home household activities from the other in-home activity types, all activities belonging to all other home activities are categorized as household activities. Under this categorization scheme, the subsample data set is used to detect the discrepancies on the temporal patterns of household activities between men and women in real life. Such discrepancies can reflect the impact of different responsibility levels on household caring duties and pose as further temporal constraints on other activities.

5.2.2 General patterns of household activities for men and women

This subsection studies the general patterns of activities that might influence men's and women's accessibilities to employment activities in the study area. The average number and duration of the selected activities between men and women will be compared. Table 5.2 shows the comparison results. Both the average number and duration of each activity type conducted by female respondents are higher than their male counterparts, and these differences are statistically significant at the 0.001 level. The results of women's higher frequency and longer time spent on drop off passenger, pick up passenger, routine shopping, and household errands suggest that women tend to shoulder more out-of-home household chores. The results of the different mean number and duration of all other home activities between men and women deserve a further investigation. As aforementioned this activity type might include activities not associated with household responsibilities. According to the previous literature (Kwan, Dijst, & Schwanen, 2007), men and women do not have significant difference in the duration of sleeping activities, but men usually spend longer time on leisure activities. Therefore, the higher frequency and duration of 'all other home activities' for female respondents would imply that women are responsible for more in-home household tasks.

Table 5.2 Average numbers and durations of the selected activities for men and women

Activity Type	Mean Activity Number			Mean Activity Duration (hrs)		
	Male	Female	Gender Difference*	Male	Female	Gender Difference*
All other home activities	2.26	2.36	0.10**	14.76	16.07	1.31**
Drop off passenger	0.12	0.22	0.09**	0.12	0.20	0.08**
Pick up passenger	0.11	0.18	0.07**	0.19	0.23	0.04**
Routine Shopping	0.33	0.52	0.19**	0.68	0.90	0.22**
Household Errands	0.11	0.16	0.04**	0.32	0.36	0.04**

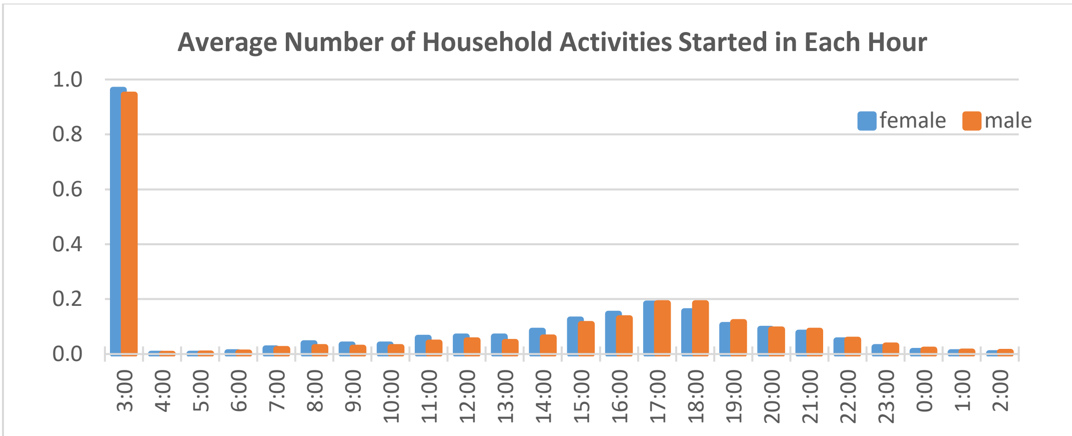
*the gender difference of mean activity number/ duration is calculated as the mean activity number/duration of female respondents minus the mean activity number/duration of male respondents.

** *p*-value of two-sample t-test smaller than 0.001

5.2.3 Time allocation patterns of activities

An investigation on the time allocations of household activities is used to gain deeper understanding on the different activity distribution patterns in time dimension between men and women and how they might influence their employment activities. Two groups of bar charts are created to study the time allocations of the household activities selected in the first subsection. One illustrates the average numbers and durations of activities starting in each hour in the survey day for male and female respondents (shown in Figure 5.2), while the other focuses on the gender difference in the average numbers and durations of activities starting in each hour in the survey day (shown in

Figure 5.3). To facilitate a more efficient detection of activity time allocation patterns, all types of selected activities are combined and shown in the same chart. To create the bar charts, all selected activities beginning in the same hour are aggregated into one group, and the average number and duration of the activities in each group is then measured and plotted on the bar charts.



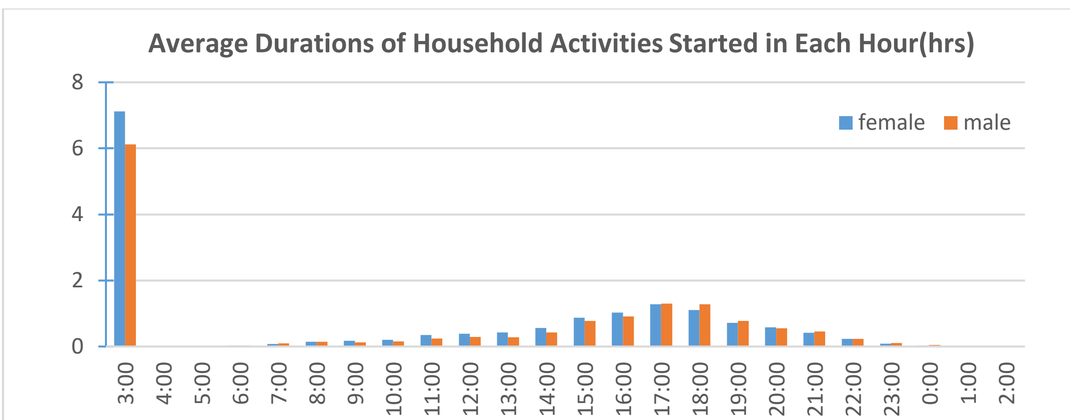
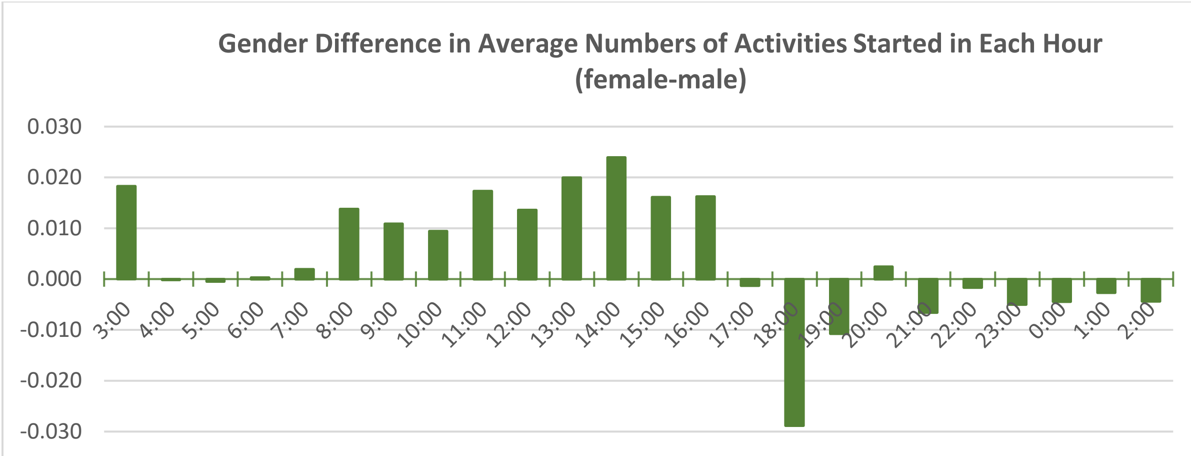


Figure 5.2 Average numbers and durations of activities started in each hour for men and women

As suggested by the bar charts, the general trends of the time allocations of the selected activities are similar between men and women. The survey starts at 3:00 when it is the time for the sleeping activity (belonging to the type of all other home activities) taken place. The much higher number and duration of activities started at 3:00 demonstrate the significance of sleeping activity to human beings and the longer time it usually takes. After 3:00, the number of activities started by men and women plummet sharply from almost one per respondent to nearly zero, as most of the respondents continue on all the other home activities and little new activity starts. From 7:00 to 11:00, the average number and duration of activities begin to increase, but in a slow speed. The type of activities started in this period mainly include all other home activities such as cooking at home, and drop off passengers such as chauffeuring children to school. From 11:00 and 17:00, the number of activities rises faster and the durations of activities also become longer, as more types of activities such as household errands, shopping and pick up children are conducted during this period. From 17:00 to 18:00, both the number and duration of activities reach to the peak, when the majority of respondents finish their work and start household related activities. After 18:00, the average number and duration of activities begin to decrease. Until 0:00 o'clock, both variables turn into almost zero as most respondents have finished the activities.



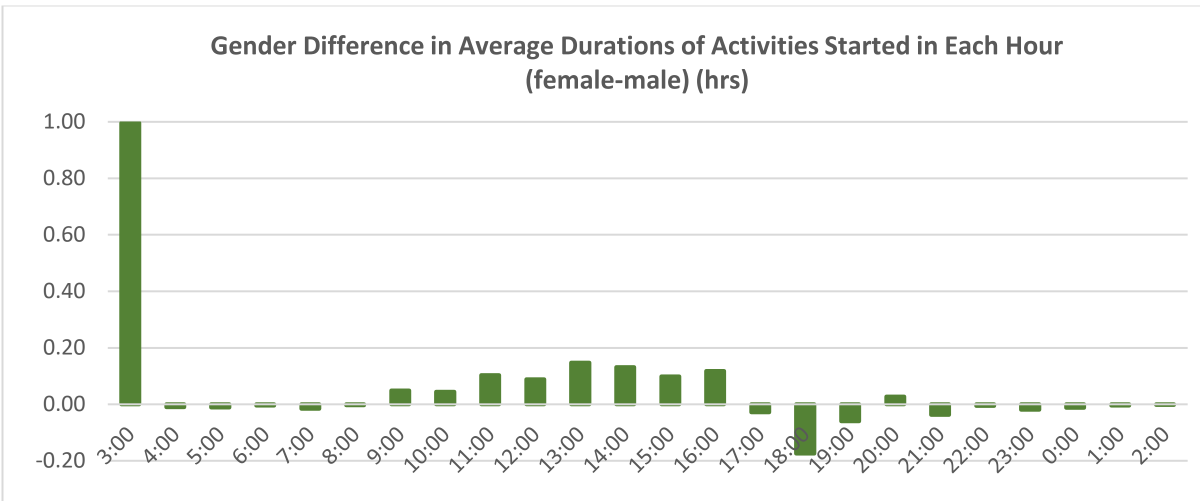


Figure 5.3 Gender difference in average numbers and durations of activities started in each hour

Two major patterns regarding the different time allocation patterns of activities between men and women are observed from the charts. First, the average duration of activities started at 3:00 for female respondents is detected to be much longer than for male respondents. As aforementioned, the majority of activities started at 3:00 belong to the ‘all other home activities’ type, which includes sleeping and in-home household activities such as cooking and house cleaning. The duration gap during the early morning period can be interpreted that women take on more household responsibilities after sleeping, which leads their ‘all other home activities’ to finish later than men. It is highly possible that such a gap will reduce the available time for women to travel to work and lead to their more limited job accessibilities. Second, the number and duration of activities starting during the day time are found to be higher for female respondents than male respondents. According to the chart, from 7:00 to 17:00 both the number and the duration of the household-related activities taken by females are larger than males, while after 17:00, the activities conducted by males exceeds females. Most employment activities are taken place during the day time. Therefore, this patterns might indicate that females' time on work is more segmented due to the needs of conducting household activities.

In summary, the analysis results of the household activity patterns of men and women reveal that 1) women tend to shoulder greater household responsibilities as indicated by women’s greater number and longer duration of household activities; and 2) the extra household-related duties cost women more time and leave shorter commuting time budget, which will constrain their accessibility to jobs. Besides, the results also suggest that women’s gender roles not only reduce women’s commuting time budget but also create constraints on their time spent on working, as suggested by their higher numbers and durations of activities during the day. These findings confirm the assumption on the different household activity patterns between the men and women made in the proposed theoretical framework and validate the mechanism on how women’s gender roles impose time constraints on their accessibility to jobs

5.3 Urban Form, Occupational Gender Segregation and Job Distributions of Different Occupations

Besides gendered commuting time budgets, job distribution patterns is the other factor that influences men and women’s job accessibilities. This section will focus on investigating how jobs are distributed in the study area. Specifically, three parts will be included in this section. Firstly, CMA’s urban form will be analyzed through a study of the spatial distribution patterns of the overall employment opportunities. Through the well-controlled simulated city models presented in Chapter

IV, the influence of different types of urban form on men and women's accessibility patterns has been examined. However, the jobs in CMA are expected to be more unevenly distributed than the models, which might lead to varying job accessibility patterns. An examination on CMA's urban form is necessary to gain a clearer understanding of how it is deviated from the job distribution settings of the models, hence facilitating a further exploration on how it will influence men and women's job accessibilities in the study area. Secondly, although the relationship between job distribution and accessibility patterns have been systematically studied in Chapter IV, the association of whether/how the different accessibility patterns between men and women will lead to the gendered occupational inequality has yet to be discussed in Chapter IV. This is mainly due to the unavailability of occupational gender segregation information for the models. CTPP 2010 provides detailed demographic worker data for CMA, which makes it possible to gain comprehensive understanding of gender distributions across occupations in the study area. In turn, the data allows for an investigation on the connection among job distribution, accessibility and occupational gender segregation. Therefore, the second part will involve an exploration on whether occupational gender segregation exists in CMA, and whether women are more concentrated in lower-paying jobs than men. It will be followed by a comparison of job distribution patterns among occupations with different income levels in the third part.

5.3.1 An exploration on the urban form of CMA

This part mainly analyzes the spatial distribution patterns of the overall employment opportunities in CMA to gain an overview of the urban form of the region. A choropleth map of job density at census tract level (shown in Figure 5.4) is created to provide a visual tool to investigate the job distribution patterns. Three major patterns are detected from the map. First, the CBD is the region's major employment center. The City of Chicago defines the CBD of the metropolitan area (the boundary of which is highlighted in yellow on the map), which includes 16 census tracts that are distributed on the lake shore (Chicago Data Portal, 2017). The CBD is rendered with the darkest shade on the map, which indicates the highest job densities of the CBD in the region. A further statistics finds that the CBD accounts for only 0.07% of the total area but possesses 11.5% of job opportunities in the metropolitan area, and its mean job density exceeds 37 times the mean job density of the region. Given the higher job densities than the other locations and the disproportionately large portion of jobs, the CBD serves as the predominant employment center for the region.

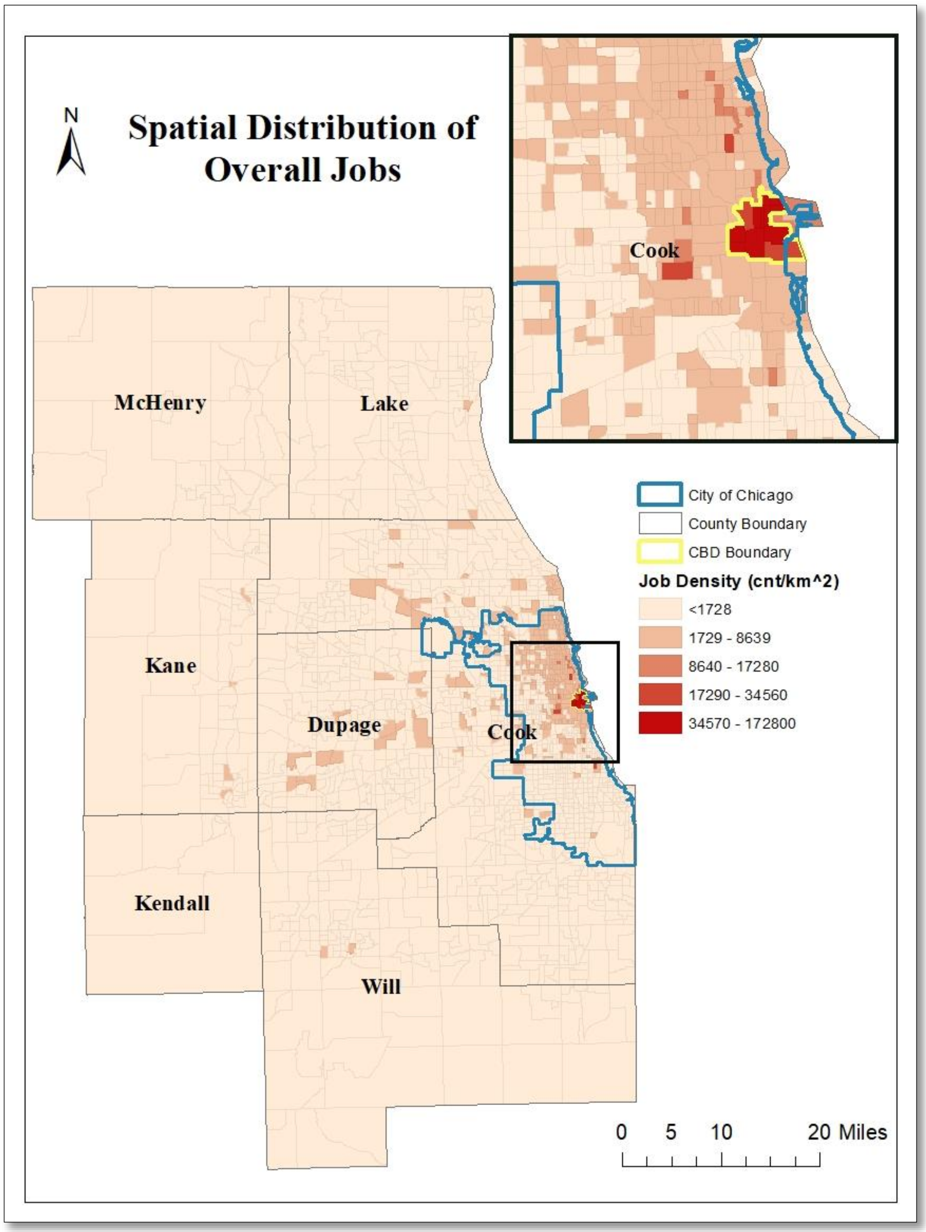


Figure 5.4 Spatial distribution of overall employment opportunities in CMA

Secondly, the region has experienced job decentralization. Many census tracts with higher job densities are found distributed outside the CBD. However, the locations of most of these census tracts are within a short distance to the CBD, while the lower job densities are mainly distributed in the remote suburb and city fringe. Only 20% of the census tracts have a job density greater than the mean value of the region, among which 86% are located within the boundary of the City of Chicago.

Thirdly, it can be found on the map that some of the census tracts with higher job densities are contiguously distributed in space, which form job clusters outside the CBD (e.g. the census tracts located at the northeast corner of DuPage County, and those distributed north of the City of Chicago on the lake shore). As suggested by the much lighter shades on the map, the densities and total number of jobs in these clusters are much smaller than the CBD. Therefore, these job clusters cannot compete with the CBD in providing as many job opportunities to the residents.

The above analysis on the spatial distribution of the overall employment opportunity in the study area demonstrates a more complex pattern than what is defined as a monocentric or polycentric urban form. The spatial distribution of jobs illustrates some monocentric pattern, as indicated by the general decreasing trends of job densities from the CBD to the city fringe. However, the multiple job clusters detected outside the CBD also imply a polycentric job distribution pattern in the region. The previous studies that focused on investigating the urban form of CMA (e.g. Wang, 1997; McMillen, 2001; Arribas-bel & Sanz-Gracia, 2014; Hajrasouliha & Hamidi, 2017) also reached different conclusions. Wang (1997), McMillen (2001), and Arribas-bel and Sanz-Gracia (2014) identified the urban form as polycentric due to the existence of job clusters outside the CBD. However, the job clusters outside the CBD were not considered as employment centers in Hajrasouliha and Hamidi's (2017) research. It is mainly based on the reason that the job clusters cannot impose much influence on residents' job accessibilities in areas where the CBD cannot, due to the proximity of these job clusters to the CBD and small portions of jobs contained in these clusters. Given the purpose of this research which mainly focus on studying people's job accessibility patterns, the author tends to agree with the Hajrasouliha and Hamidi (2017)'s conclusion and assumes that the accessibility patterns for men and women in the study area will be more similar with the accessibility patterns from a monocentric form. However, given the more complex job distribution patterns of the CMA, the job accessibilities for men and women are also expected to show some distinct patterns from the accessibility patterns derived from the well-controlled monocentric models.

5.3.2 Distribution of men and women across occupations

This subsection will study the occupational gender segregation situation in CMA. The data used for examining the shares of men and women in various occupations is extracted from CTPP. CTPP 2010 divides occupations into 24 groups. Three of them, including 1) farmers or farm managers, 2) farming, fishing, and forestry occupations, as well as 3) occupation in armed forces, are not included in this study, since they are not typical occupations in an urban environment and they in total account for only 0.4% of the region's overall employment. The remaining 21 occupations (listed in Table 5.3) fall in the following five major categories (BLS, 2012): 1) Management, professional and related occupations, 2) service occupations, 3) natural resources, construction, and maintenance occupations, 4) sales and office occupations, and 5) production, transportation, and material moving occupations. The median income of the 21 occupation groups are calculated based on the 2006-2010 ACS 5-years Estimates and shown in Table 5.3 in descending order. As expected, occupations with the highest median income are majorly in the category of management and professional related occupations, while service or production oriented occupations tend to located at the bottom of the income rankings. If dividing the occupations into three groups at the break points of $50,000 and $30,000 based on the occupations' median income, and denoting the groups as high-income, medium-income and low-income occupations respectively, patterns can be found regarding the occupation compositions in different groups. All the seven occupations in the high-income occupation group belong to the management, professional and related occupation category. The median-income occupation group includes a mix of occupations in multiple categories, including management,

Table 5.3. The median income, gender composition and category of occupations in CMA

Occupations	Occupation Category*	Median Income($)	Occupation Groups by Income	%Females in Occupations / %Females in Labor Force
Legal occupations	1	83638	High-income Occupation Group (>$50000)	0.98
Management occupations	1	73321		0.833
Computer and mathematical occupations	1	71277		0.597
Architecture and engineering occupations	1	69356		0.311
Business and financial operations occupations	1	59315		1.09
Healthcare practitioner and technical occupations	1	55186		1.587
Life, physical, and social science occupations	1	54981		0.983
Protective service occupations	2	48082	Medium-income Occupation Group ($30000 ~ $50000)	0.515
Installation, maintenance, and repair occupations	3	44610		0.102
Construction and extraction occupations	3	41128		0.005
Education, training, and library occupations	1	40547		1.588
Community and social services Occupations	1	38919		1.382
Arts, design, entertainment, sports, and media occupations	1	38866		1.05
Sales and related occupations	4	33445		1.009
Office and administrative support occupations	4	29995	Low-income Occupation Group (<$30000)	1.533
Production occupations	5	29294		0.694
Transportation and material moving occupations	5	27724		0.395
Healthcare support occupations	2	22314		1.862
Building and grounds cleaning and maintenance occupations	2	20752		0.813
Food preparation and serving related occupations	2	14909		1.048
Personal care and service occupations	2	14120		1.671

*1. Management, professional and related occupations; 2. Service occupations; 3. Natural resources, construction, and maintenance occupations; 4. Sales and office occupations; 5. Production, transportation, and material moving occupations.

professional and related occupation category, sales and office occupation category, construction related occupation category, and service occupation category. The low-income occupation group concentrates on all the occupations in production, transportation and material moving category, most occupations in service occupation category, as well as one occupation in sales and office occupation category.

The degree of concentration of female workers in the 21 occupation group are studied to investigate the occupational gender segregation in the study area, and to explore if female workers concentrate in the traditionally female-dominated occupations, which tend to be non-professional and with lower incomes. The level of women's concentration in a specific occupation group is calculated as the ratio of the proportion of women in the occupation group to the proportion of women in the labor force (Weinberger, 2007). A ratio higher than 1 indicates there are more female workers concentrated in the occupations than in the labor force. The occupation group is considered as female dominated is the ratio if larger than 1.25. In the contrast, a ratio below 1 suggests there are more male workers in the occupations and if the ratio is lower than 0.75 then the occupation group is considered as male-dominated (Weinberger, 2007). The gender composition data in each occupation group as well as in the labor force is also extracted from the 2006-2010 ACS 5-years Estimates.

The results (shown in table 5.3) of the degree of concentration of female workers indicate the existence of occupational gender segregation in the study area. Among the 21 occupation groups, six have women's concentration ratios above 1.25, including healthcare practitioner and technical occupations, education, training and library occupations, community and social services occupations, office and administrative support occupations, healthcare support occupations, and personal care and service occupations, which are highly accordant with the conventional understanding of female-dominated jobs. Seven occupation groups have a ratio below 0.75. Two of them fall in the management and professional related category which include computer and mathematical occupations, Architecture and engineering occupations, and the others are majorly related with production, transportation or installation and construction occupation category, which are also the typical types of male-dominated occupations.

The results also illustrate that most of the female-dominated occupations tend to be distributed in the low-income occupation group. Among the six female-dominated occupations, only one occupation group fall in the high-income occupation group, while three of them are in the low-income occupation group. However, five of the seven male-dominated occupations have median income above \$40,000, and two of them are even around \$70,000. Given the uneven distribution of men and women in the three occupation groups, the space-time accessibilities of jobs to these occupations are studied for men and women to explore the connection between job accessibilities and the gender occupational segregation. The spatial distribution of jobs in the three occupation groups will be investigated in the next subsection.

5.3.3 Comparison of spatial distribution patterns of jobs among occupation groups

The previous subsection has confirmed the existence of occupational gender segregation and women's underrepresentation in high-income occupations. This subsection would like to find out the different job distribution patterns among the three occupation groups. Based on a statistically significant relationship between women's short commuting distance and their high likelihood of being in non-professional and lower-paid occupations, Wyly (1998) suggests a more dispersed distribution of the low-paying occupations which provides women (whose commuting distances are restricted by their household responsibilities) easier access and hence leads to their higher concentration in these occupations. Chapter IV finds that the model with a more dispersed job distribution (e.g. a monocentric model with a larger CBD size but a lower degree of concentration of jobs in the CBD) tends to correspond to women's less disadvantageous status in competing job opportunities with men. Based on Wyly's (1998) study and the results of Chapter IV, the author would like to confirm whether the high-income occupations would have a more compact job distribution patterns than the other two groups in this subsection.

Before diving into the job compactness comparison, the general spatial distribution patterns of jobs for the three occupation groups are studied. Choropleth maps of job density at census-tract level (shown in Figure 5.5) are produced for the three occupation groups to help understand their spatial distribution patterns of jobs. The maps suggest that all three occupation groups inherit the general distribution patterns of overall employment opportunities. The general job distributions show monocentric patterns, with most census tracts with the highest job densities concentrated in the CBD area. However, job clusters can also be detected outside the CBD area, but the job densities in these clusters are much smaller than in CBD.

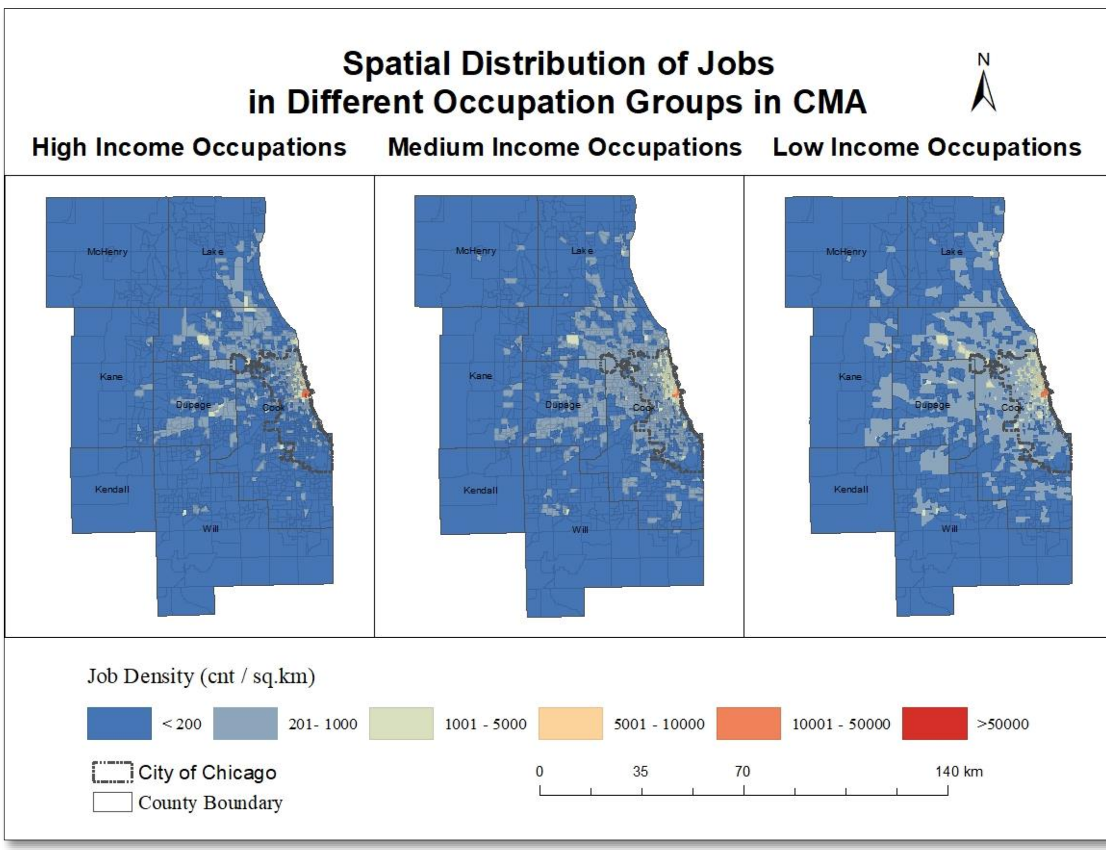


Figure 5.5 Spatial distribution patterns of jobs in three occupation groups

Two measures will be adopted to help analyze the compactness variations among the occupation groups: mean center and standard distance. Mean center is the average (x, y) coordinate of a group of features on the ground. It is useful for comparing the distribution of different types of features, because its location can usually indicate where the features tend to be more frequently located in space. In many cases, features have varied importance in the distribution. Therefore, weight can be added to the mean center measure to help more accurately depict the central tendency of the distribution. In this research, a job-weighted mean center will be calculated for each occupation group. The equation for this job-weighted mean center is

$$(\bar{x}_w, \bar{y}_w) = \left(\frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}, \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \right)$$

where $(\bar{x}_w, \bar{y}_w)$ denotes the job-weighted mean center, w_i is the job counts at census tract i, (x_i, y_i) is the coordinate of the centroid for census tract i, and n is the total number of census tract in CMA. By comparing the locations of the job-weighted mean centers, places where more jobs are distributed in the occupation groups can be detected. The mean center will be drawn closer to the area if there are larger amount of jobs in this area than in the others.

Standard distance is the average distance of a group of features to their mean center. It is used to measure the extent to which the features are concentrated or disperse around the mean center. The smaller the standard distance, the more compact the distribution of features is. Similarly, a weight can be added to adjust the importance of the features in the distribution. A job weighted standard distance will be used to compare the spatial compactness of jobs among the three occupation groups. The job-weighted standard distance is calculated as

$$SD_w = \sqrt{\frac{\sum_{i=1}^{n} w_i (x_i - \bar{x}_w)^{\wedge}2}{\sum_{i=1}^{n} w_i} + \frac{\sum_{i=1}^{n} w_i (y_i - \bar{y}_w)^{\wedge}2}{\sum_{i=1}^{n} w_i}}$$

where SD_w defines the job-weighted standard distance, $(\bar{x}_w, \bar{y}_w)$ denotes the job-weighted mean center, w_i is the job counts at census tract i, (x_i, y_i) is the coordinate of the centroid for census tract i, and n is the total number of census tract in CMA. A smaller value of the job-weighted standard distance indicates a more compact distribution of jobs of the occupation group. In contrast, a larger value suggests a more disperse distribution.

Table 5.4 Mean centers and standard distances of the three occupation groups

Occupation Groups	Standard Distance (km)	Distance from Mean Center to CBD (km)
High Income	27.1	19.9
Medium Income	29.18	21.02
Low Income	28.94	21.62

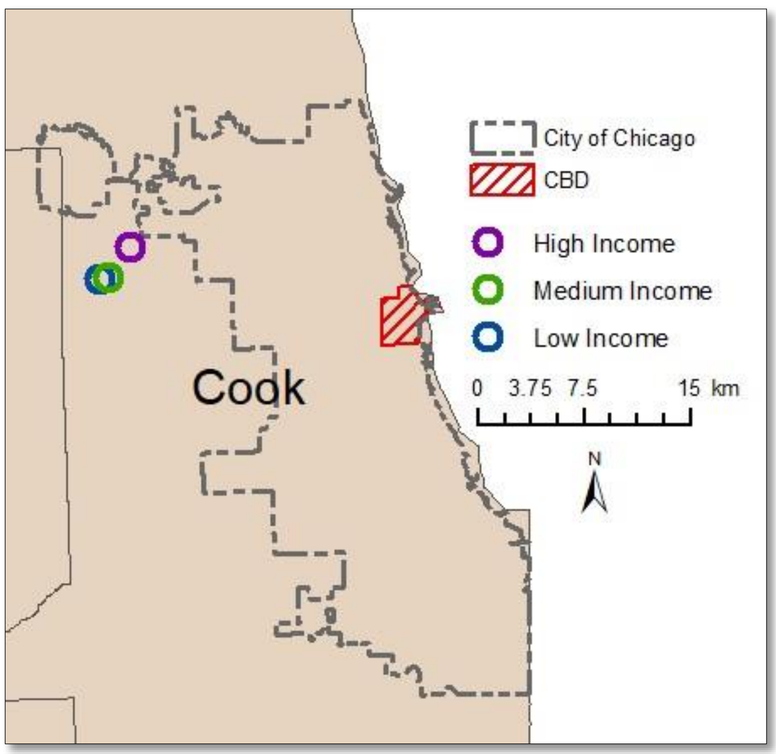


Figure 5.6 Spatial distribution of three mean centers

The result of the standard distance for each occupation group is listed in Table 5.4. To help better understand the difference of the mean center location among the occupation groups, a map showing the distributions of the mean centers (shown in Figure 5.6) is created and the distances from the mean center of each occupation group to the CBD is also listed (in Table 5.4). Table 5.4 indicates that the compactness variations among the three occupation groups match the author's hypothesis. Based on the calculation results, the high-income occupation group has the most compact job distribution among the three, as indicated by its smallest standard distance value. The standard distance values of the other two occupation groups tend to be similar with each other, suggesting a similar compactness level of job distributions.

For the locations of the mean centers, Table 5.4 demonstrates that the mean center of the high-income occupation group is the closest to the CBD among the three occupation groups, suggesting a larger proportion of high-income job opportunities concentrating in and/or around the CBD area than the other two occupation groups. Besides, Figure 5.6 shows that the mean center of the high-income occupation group is located further north than the other two occupations. It indicates a greater percentage of high-income jobs located in the north, which might offer easier access for men and women living in the north of the region to these jobs.

5.4 Accessibility to Employment Opportunities

The analysis on the two factors that influence men and women's job accessibility patterns in CMA in section 5.2 and 5.3 illustrate that: 1) women spend longer time on household-related activities which can restrict their available time spent on work; and 2) CMA has a more complex urban form which carries both monocentric and polycentric characters, and the high-income occupation group, in which women are underrepresented than men, has a more compact job distribution than the medium-income and low-income occupation groups. The joint influence of the above two factors on men and women's job accessibility patterns in the study area will be investigated in this section. Specifically, two main questions will be investigated. First, given the more complex urban form of CMA, how will job accessibility for men and women vary across the metropolitan area and how will the patterns differentiate from those derived from the simulated models? Secondly, how will the variations in the distribution patterns of different income-level occupations affect gender's accessibility to those jobs and contribute to women's lower presentation in high-income jobs in CMA?

In order to answer the questions, men and women's job accessibilities will be measured using the methodology framework presented in Chapter III. The two factors influencing men and women's accessibility patterns are set as follows for the measurement. First, based on the conceptual framework proposed in Chapter III, men and women's work time budget can be determined mainly by the time spent on activities that have higher priorities over work, including personal care activities for men, and both personal care activities and household activities for women. However, the time spent on personal care activities of the respondents in CMA is not provided in CTPP data, hence the time budget for commuting cannot be derived directly from the data set. As an alternative, this research chooses 45 minutes and 15 minutes as the commuting time budgets for male and female workers respectively. Even though these numbers do not reflect the true time budgets for men and women, they offer a reasonable depiction of the gender difference in commuting time budgets and can help people understand the impact of shorter time budgets on women's job accessibility patterns. Secondly, the CTPP place of work data is utilized as the data source to portray the distribution of job opportunities, and census tract is chosen as the basic spatial unit for this analysis.

Besides these two factors, travel methods can also influence people's space-time accessibility. As most people commute to work in their private cars, automobile travel via the road network, instead of straight-line distance, is used in this study for accessibility measures. The road network data is obtained from the Tiger/Line Shapefiles released by the United States Census Bureau (2010). Three levels of roads are included in the network: the primary, secondary, and local neighborhood roads. They are respectively assigned with the free flow speeds of 60 miles per hour (mph), 35mph, and 25mph. The different levels of roads are unevenly distributed across the metropolitan area. Therefore, compared with the straight-line distance measurement method used in the models, the road-network distance measurement may lead the accessibility distribution in CMA to show distinct patterns that have not been detected from the simulated models.

5.4.1 Accessibility to overall employment opportunities in CMA

Men and women's accessibilities to overall employment opportunities in CMA will be studied in this part. In particular, the study will focus on the comparison between the overall job accessibility patterns in the metropolitan area and the accessibility patterns in the simulated model, which helps build a deeper understanding on how the more complex urban form of CMA will influence the job accessibility patterns of the residents.

To facilitate analyzing the spatial distribution patterns of men and women's accessibilities to overall job opportunities, choropleth maps of accessibility at census-tract level (demonstrated in figure 5.7) are created for men and women. The accessibility value shown on the maps is the percentage of jobs, instead of the number of jobs, men or women can access at each census tract. It is calculated by dividing the number of jobs men or women can access at one census tract by the total number of jobs distributed in the study area. Due to the large gender gap in commuting time budget, the number of jobs men and women can access show large variations. The number-to-percentage conversion places men and women's accessibilities on the same scale, which makes it easier to compare the distribution patterns of accessibilities between men and women. Four classes are included in each map, which are denoted as high accessibility class, moderate-to-high accessibility class, low-to-moderate accessibility class and low accessibility class respectively. Quantile classification scheme is adopted for classifying the accessibility data, and hence each class contains 25% of census tracts of the region. This classification method allows for efficiently detecting gender differences in accessibility patterns through comparing distribution of census tracts and accessibility values of the same quartile between men and women.

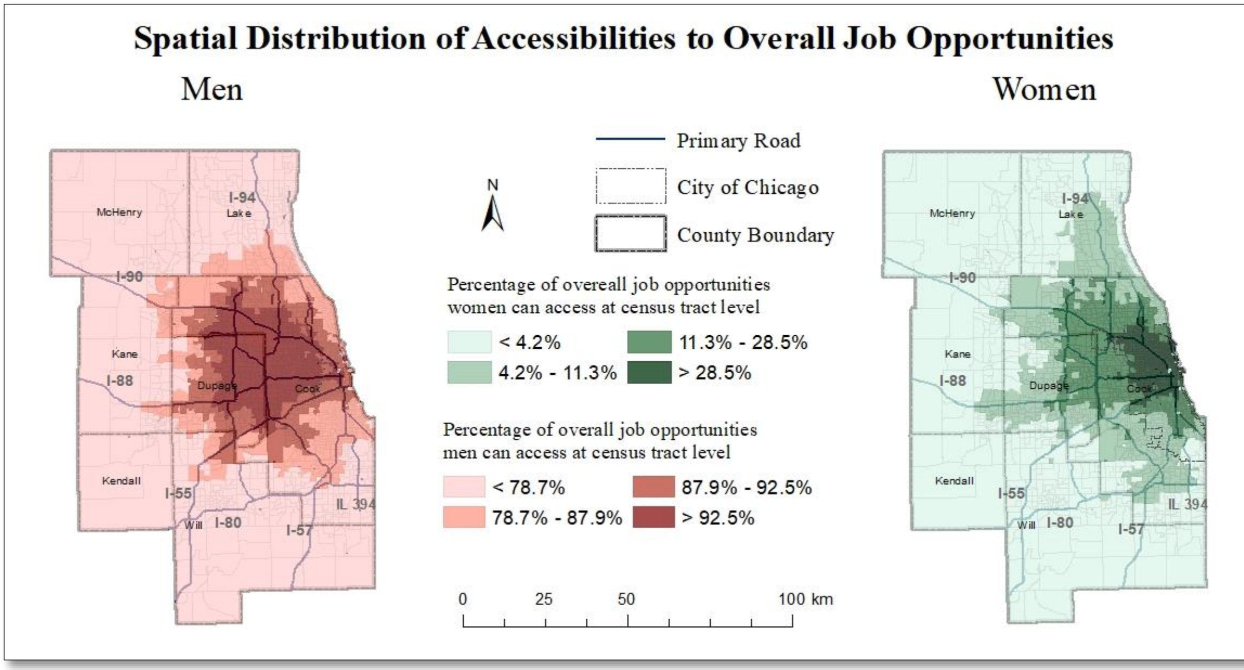


Figure 5.7 Spatial distribution patterns of men and women's accessibilities to overall job opportunities

<u>General spatial distribution patterns of accessibility to overall employment opportunities</u>

As expected, the distribution of the overall job accessibility for men and women in CMA demonstrates more complex patterns than those in the simulated models created in Chapter IV, showing the influences of the more complex urban form of the CMA. In addition, the way how travel distance is measured also leads to the varied accessibility patterns between CMA and the models.

The general spatial distributions of the overall job accessibilities for men and women does not show great deviation from the simulated monocentric models. Based on the maps, the locations which provide men/women the highest job accessibilities are distributed contiguously over space, while the other accessibility classes surround high accessibility class in a way that census tracts with lower accessibility classes tend to be distributed further from the high accessibility class. Such spatial distribution patterns might be explained by the fact that the spatial distribution of overall jobs generally demonstrate monocentric patterns. Although multiple job clusters are detected outside the CBD, they have lower job densities than the CBD and the majority of them tend to be distributed around the CBD area. Therefore, they mostly promote the accessibilities in areas within/or surrounding the CBD area but do not create other clusters of peak accessibilities in the region.

However, a close observation of the maps also reveals patterns that are different from the simulated models. First, the area where men/women are able to enjoy the highest job accessibilities among the others are not centered on the CBD of the region. The locations where women can access the highest overall employment opportunities tend to concentrate in the northern part of the City of Chicago, which is at a certain distance away from the CBD. Compared with women, the peak accessibilities for men are distributed even further from the CBD, which are mostly in west Cook (outside the City of Chicago) and northeast DuPage County. This distinct pattern shown in CMA is a result from the specific job distribution settings that deviate from the simulated models. Because the CBD in the models is located in the geographic center, the accessibilities peak at the CBD and then decrease towards the metropolis fringe for men and women. However, the CBD in CMA is located on the region's boundary, where men and women have more limited job search range. Therefore, the areas where men and women can access the highest percentage of jobs are in a certain distance away from the CBD and pulled closer to the region's center.

Secondly, the higher accessibility classes radiate out through transportation corridors in the study area, which is probably because of the different travel cost measurement methods used in CMA from in the models. In the well-controlled simulated models, residents travel between work and home in straight distance with identical travel speed across the region. Job distribution pattern, which is translated into straight-line distance measure, becomes the sole spatial factor to determine accessibility in the simulated models. In real-world cities, people travel through road networks which distributed unevenly across the space with varying travel speed. Those who can access the major roads within the time budgets for traveling to work are able to travel longer distances and gain higher job accessibilities.

Thirdly, there are several isolated census tracts located further away from the CBD, but having a similarly high accessibility measure as those clustering closer to the CBD on each map. The uneven distribution of the road networks may contribute to the existence of these islands. The more complex job distribution, such as local small jobs clusters at isolated locations outside the CBD, may also lead to such accessibility patterns. Although the job clusters do not create other accessibility peaks, it is highly possible that they will gently increase the job accessibilities in certain locations, which leads the job accessibilities in these locations to be slightly higher than its surrounding areas, hence producing a more uneven accessibility distribution patterns than the monocentric models.

Gender differences in accessibility to overall employment opportunities

A comparison of the overall job accessibilities between men and women shows gendered patterns. Due to the shorter commuting time budget, women have much lower accessibilities than men (Table 5.5). In addition, the accessibility value range varies significantly higher across classes for women in comparison to that for men. Based on Table 5.5, the upper limit for the high accessibility class is less than 1.5 times of the upper limit for the low accessibility class for men, but the ratio jumps up to 10 times for women. Such great variation can also be attributed to women's more limited commuting time budget, which leads to their accessibilities being more sensitive to the changes in job densities at different locations in the region. In this case, residential location plays more important roles in determining women's job accessibilities. Changing locations will not largely alter men's accessibilities, but the experience of accessing jobs for women will be significantly different in varying parts of the region.

Table 5.5 Percentage of jobs men and women can access in each accessibility class

	Accessibility Value Range					
	Male			Female		
	Lower	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**
High Accessibility Class	2.37%	78.70%	56.05%	0.02%	4.24%	2.41%
Moderate-to-High Accessibility Class	78.70%	87.85%	83.80%	4.24%	11.34%	7.35%
Low-to-Moderate Accessibility Class	87.85%	92.51%	90.56%	11.34%	28.52%	19.40%
Low Accessibility Class	92.51%	97.19%	94.20%	28.52%	43.37%	33.72%

Besides the differences in accessibility values, men and women's accessibilities also show varying patterns regarding where each accessibility class is located. As discussed in the previous subsection, an obviously further distance of the high accessibility class to the CBD for men than women is detected from the choropleth maps. This gender difference can also be explained by the commuting time budget gap between men and women. Men have a much larger job search area due to the longer commuting time budget. Therefore, the highest accessibility locations of men tend to be closer to the geometric center of the region, which assures that all or the majority part of the job search range will fall within the boundary of the region. On the contrary, women's shorter time commuting budget forces women to live closer to the CBD to access the large amount of jobs there and hence gain the highest accessibility. In addition, the spatial locations of the other accessibility classes also demonstrate some different patterns between men and women. For example, the overall distribution of the women's moderate-to-high accessibility census tracts shifts closer to the CBD area and the men's low-to-moderate class includes more census tracts located near the lake shore than women.

Finally, the maps also indicate that the spatial distribution of the street network tends to impose more significant influence on women's spatial distribution of job accessibilities than on men's. The spatial distribution of women's job accessibilities exhibit a stronger pattern that the accessibility classes radiate out along the major routes. For example, both men and women have a part of the low-to-moderate accessibility class extending along I94 to the north and I88 to the west, but the length of this part is greater for women than for men. This is also due to women's short commuting time budget which leads them to be more sensitive to accessibility changes. As a result, residing within short distances from the major transportation routes will be more meaningful for women in enhancing their job accessibilities than men.

5.4.2 Comparison of accessibility patterns among three occupation groups

This section will discuss men and women's accessibility patterns for high-income, medium-income and low-income occupation groups, with the aim of understanding if and how the accessibility variations for different income level occupation groups lead to women's more disadvantageous status in accessing high-income job opportunities. Choropleth maps of accessibility at census-tract level are also established for each occupation group for men and women (shown in Figure 5.8 and 5.9) to present the spatial distribution patterns of accessibilities. In these maps, the accessibility values are shown as the percentage of jobs in one particular occupation group men/women can access at a census tract, which is calculated as the ratio of the number of jobs in this occupation group accessible at the census tract over the total number of jobs in this occupation group in CMA. The purpose of utilizing the percentage of jobs instead of number of jobs is also to put the accessibilities for different gender and occupation groups on the same scale, which facilitates the comparison of their accessibility distribution patterns. The accessibility values for each occupation group are also divided into four classes, defined as high accessibility, moderate-to-high accessibility, low-to-moderate accessibility, and low accessibility. The same class break values used for dividing the accessibility to overall jobs will be utilized in this subsection to classify the accessibility to the three occupation groups of the same gender.

Due to the resemblance of the job distribution patterns between the occupation groups and the overall employment opportunities, the spatial distribution patterns of job accessibilities for the three occupation groups show similarities with the spatial distribution patterns of overall job accessibilities of the same gender group. The accessibilities for men and women for the three occupation groups are distributed generally in a monocentric way, but more uneven patterns are also detected than in the simulated monocentric models. In addition, the disadvantage of women in overall jobs has been inherited by each individual occupation group, as indicated by women's much lower accessibilities than men for each occupation group and the larger variations of accessibilities among different locations.

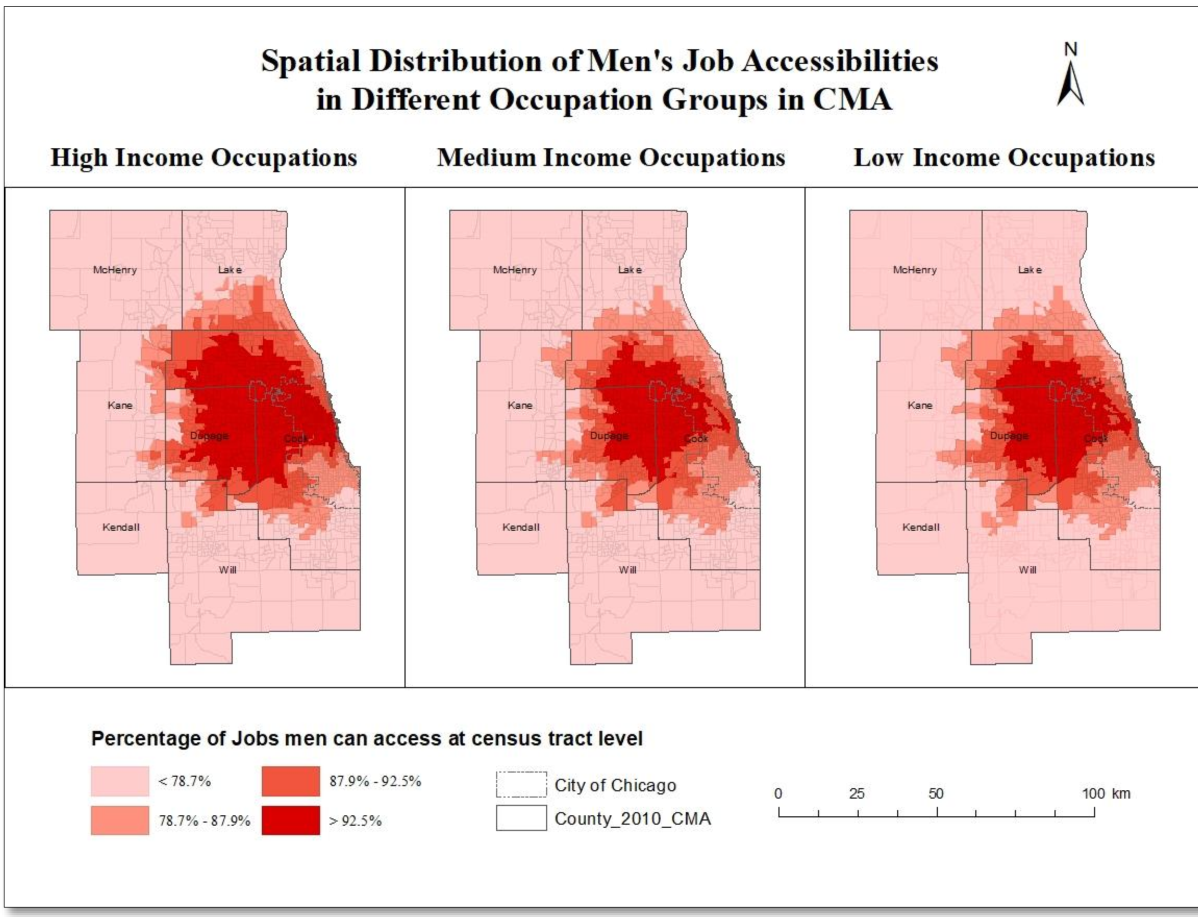


Figure 5.8 Spatial distribution patterns of men's accessibilities to the three occupation groups

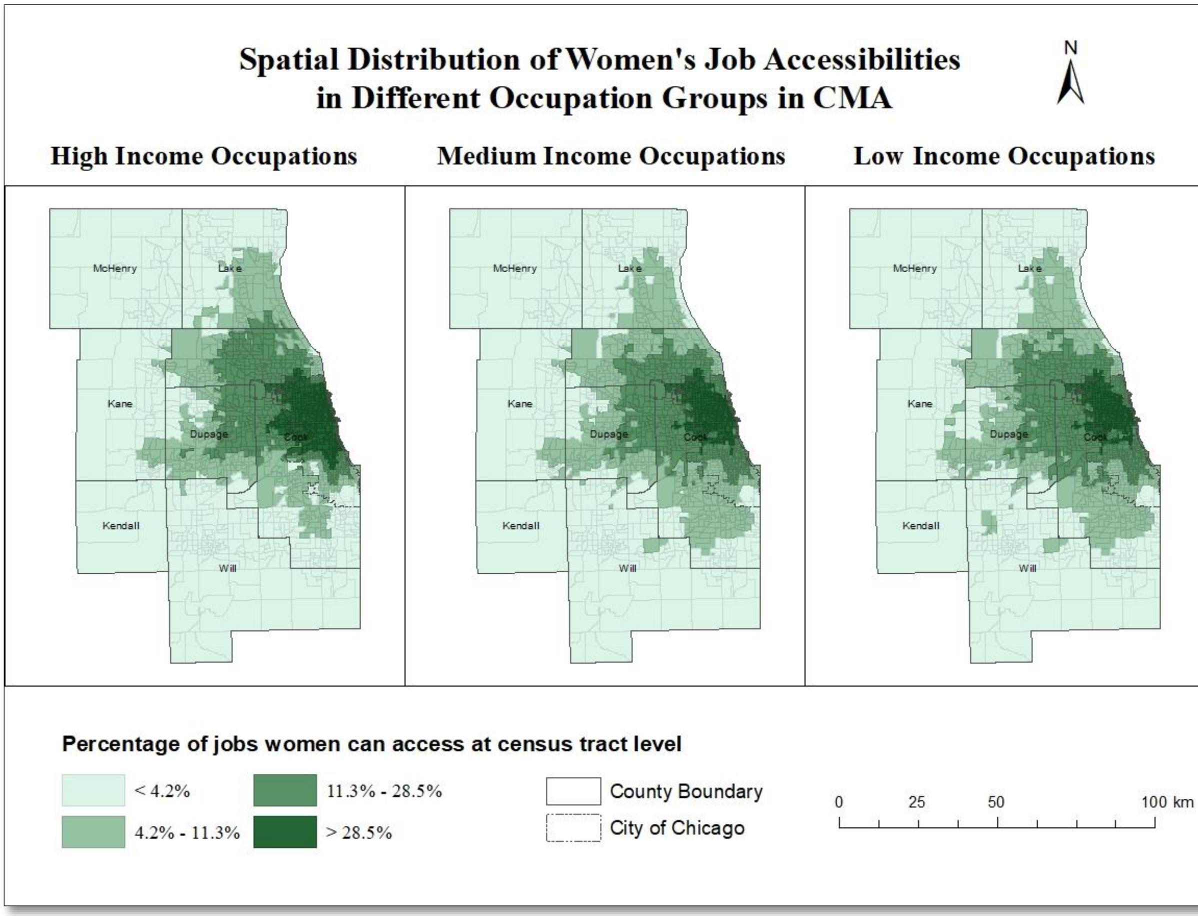
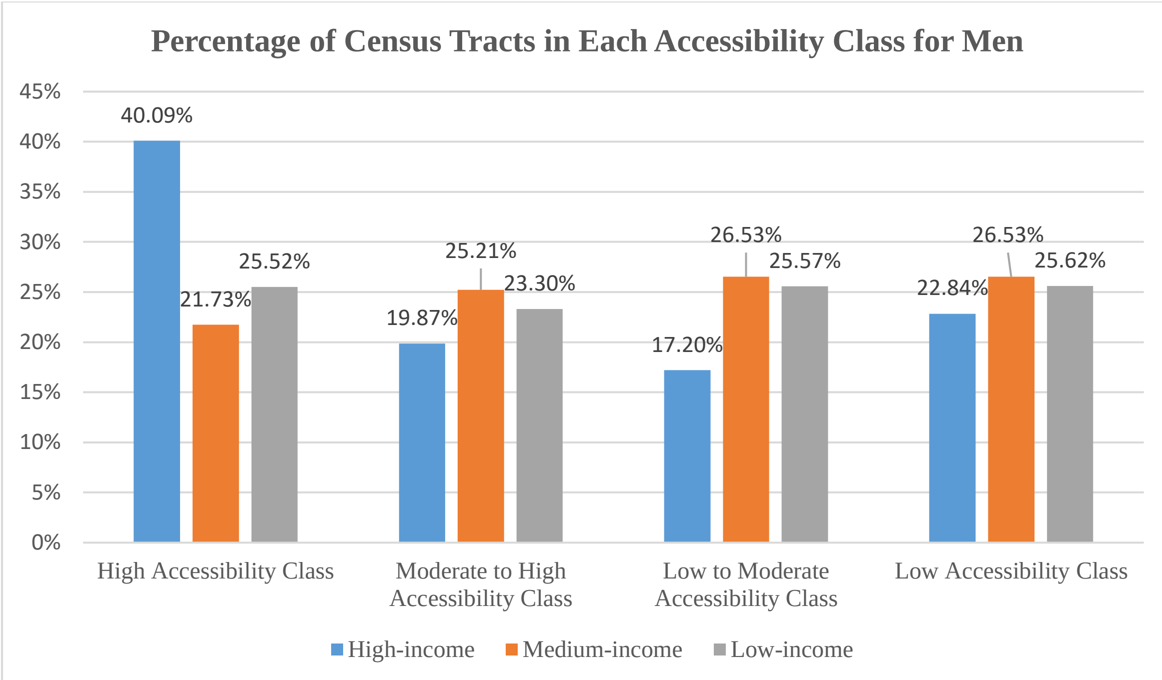


Figure 5.9 Spatial distribution patterns of women's accessibilities to the three occupation groups

Variations can also be discerned among the occupation groups from the maps, which mainly lie in the different sizes of area covered by each accessibility class. For example, the high accessibility class for high income occupations accounts for a larger area than the other two occupations on the maps for both gender groups, indicating that men and women in a larger area are able to gain a higher level of job accessibilities for high income occupations than the other two occupation groups. However, such differences in the other three accessibility classes are not easy to be identified from the maps given the way how these classes are distributed around the high accessibility class. Therefore, the proportions of census tracts falling into each accessibility class for the three occupation groups are calculated to help gain comprehensive understanding of the differences among the occupation groups.



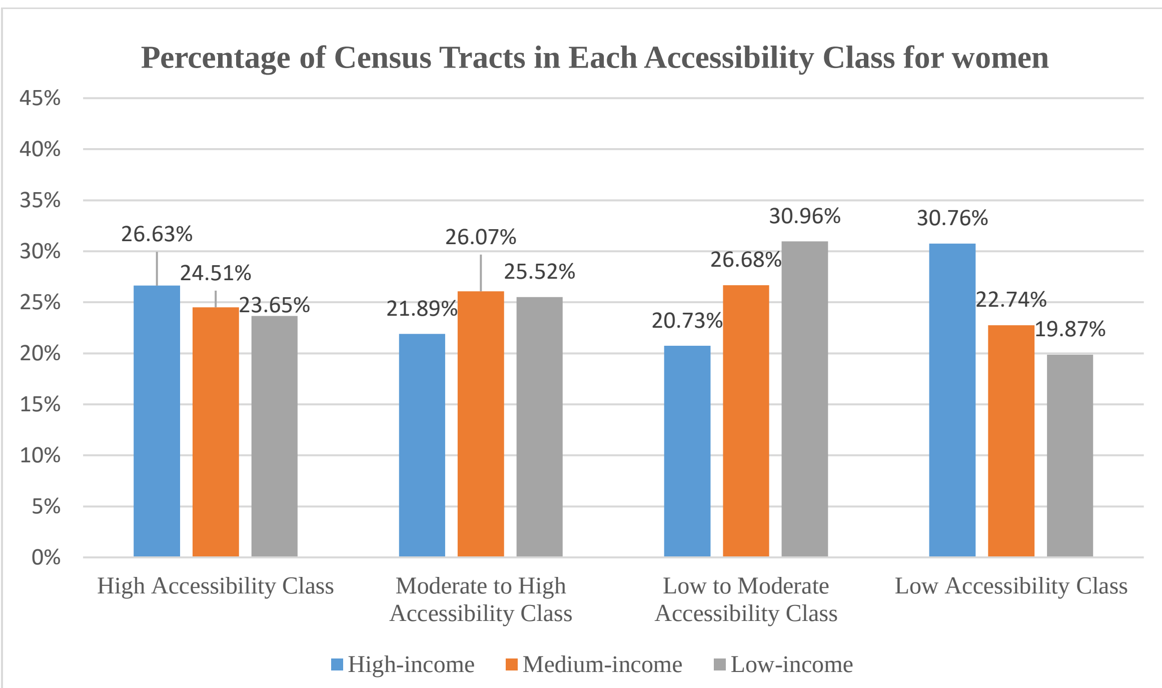


Figure 5.10 Percentage of census tracts in each accessibility class for men and women

The bar charts reveal obvious differences in proportion distribution of census tracts among the three occupations for both gender groups. Compared with the medium-income and low-income occupation groups, there are more census tracts where men are able to gain a higher level of job accessibilities for the high-income occupation group. According to the bar charts, the percentage of census tracts falling into the high accessibility class for men is over 40% for high income occupations, but only about 22% and 26% for medium-income and low-income occupation groups. In addition, there are less census tracts where men will experience moderate and low level of job accessibilities for the high-income occupations than the other two occupation groups. While the high-income occupation group's proportions of census tracts in moderate and low accessibility classes range from 17% to 23% for the high-income occupations, the proportions are all above 23% for these accessibility classes for medium-income and low-income occupations. The different spatial compactness of job distributions among the three occupation groups can be used to explain these variations in census-tract proportional distributions. The high-income occupation group has a more compact distribution of jobs in space. A considerably large percentage of the high-income jobs tend to be distributed in smaller areas. Therefore, it is easier for men to access high proportions of jobs in a larger area of the region. However, the job distributions of medium-income and low-income occupations are more dispersed. The same large percentage of jobs in these two occupation groups will scatter over a wider area, which restricts many from accessing as high a percentage of jobs for the high-income occupation group as for the medium-income and low-income occupations.

Women's patterns are different from the men's. Although there are slightly more census tracts where women will enjoy high job accessibilities to high-income occupations than medium-income and low-income occupations, the proportion of census tracts where women will struggle with low job accessibilities to high-income occupations is also greater than the other two occupation groups. The bar charts show that the percentage of census tracts distributed in high accessibility class is around 2%-3% greater for high-income occupations than the medium-income and low-income occupation groups. Such a gap for women is much narrower than for men. The main reason can probably be attributed to the shorter commuting time budget for women, which leads women to only access a part of the jobs concentrated in CBD and its surrounding area, hence reducing the variation in the percentage of census tracts falling into the high accessibility class among the three occupation groups. The bar charts also indicate that high-income occupations have 8%-10% more census tracts distributed in low accessibility class. This is also associated with women's more limited commuting time budget, due to which women are not able to reach the CBD and its surrounding area in a large area in the region. The high-income occupations are more compactly distributed, meaning a greater proportion of high income jobs distributed in and around the CBD area but less scattered in the suburbs and metropolis fringe. Therefore, women in more locations tend to access a very low proportion of jobs for high income occupations than for the other two.

Based on the above analysis, it can be concluded that high-income occupations tend to have an advantage over the other two occupations for men to access, in terms of the easiness of men to access larger proportions of high-income job opportunities in more locations in the region. However, women's census tract distributions cannot lead to the same conclusion: although there are more women surrounded by a high percentage of high-income jobs, there are also more women who can only reach a very limited proportion of high-income jobs compared with medium-income and low-income job opportunities. As a result, while more men are able to choose high income occupations due to the accessibility advantage, it is not the case for women. Such gender differences indicate the disadvantage of women in competing high income job opportunities with men in the region, which might partially explain women's underrepresentation in these occupations.

Location quotient of accessibility for the three occupation groups

The choropleth maps of job accessibilities and the bar charts have demonstrated the general spatial distribution patterns of job accessibilities to the three occupation groups for men and women, as well as the variations in the proportion of census tracts in each accessibility class among the three occupation groups. Based on the census tract proportion differences derived from the bar charts, women's difficulty of accessing high-income jobs compared with men has been illustrated, which can be used to explain the unequal gender allocation in high-income occupations. However, since the three occupation groups do not show large differentiations in spatial distribution patterns, the locations which particularly provide easier access to high-income occupation group for women remain unclear. Therefore, the current analysis cannot offer enough information to help women find the places that offer high accessibility and improve their disadvantageous status in accessing high-income jobs. In order to further obtain the associated information, location quotient (LQ) of job accessibility at census tract level will be measured in this part.

LQ is a widely-used tool in economy geography for identifying industries or occupations that are specialized to a region because of their higher than average share in the entire country. In this part, the LQ measure will be used to identify the occupation that is unique at a census tract for wo/men to access. It will be calculated by dividing the proportion of accessible jobs in one occupation group among the overall accessible jobs at a census tract by the proportion of total jobs in this occupation group among the overall jobs in the metropolitan area. A LQ equivalent to one indicates that the accessible employment at this census tract matches the proportion of regional employment in the particular occupation group. A LQ lower than 1 indicates that the accessible employment at this census tract is less than the average share of the region. On the contrary, a LQ larger than one indicates that there are greater proportion of employment concentrate in the search area of men/women at this census tract compared to the regional average.

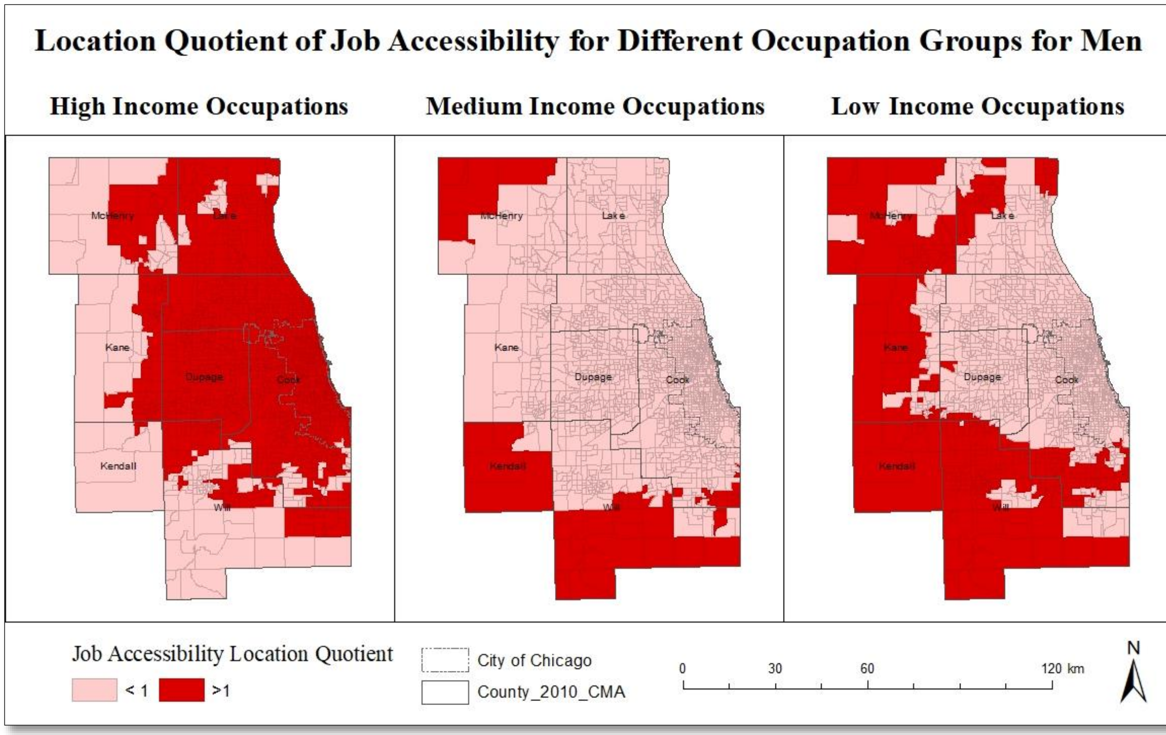


Figure 5.11. Spatial distribution of men's LQs for the three occupation groups

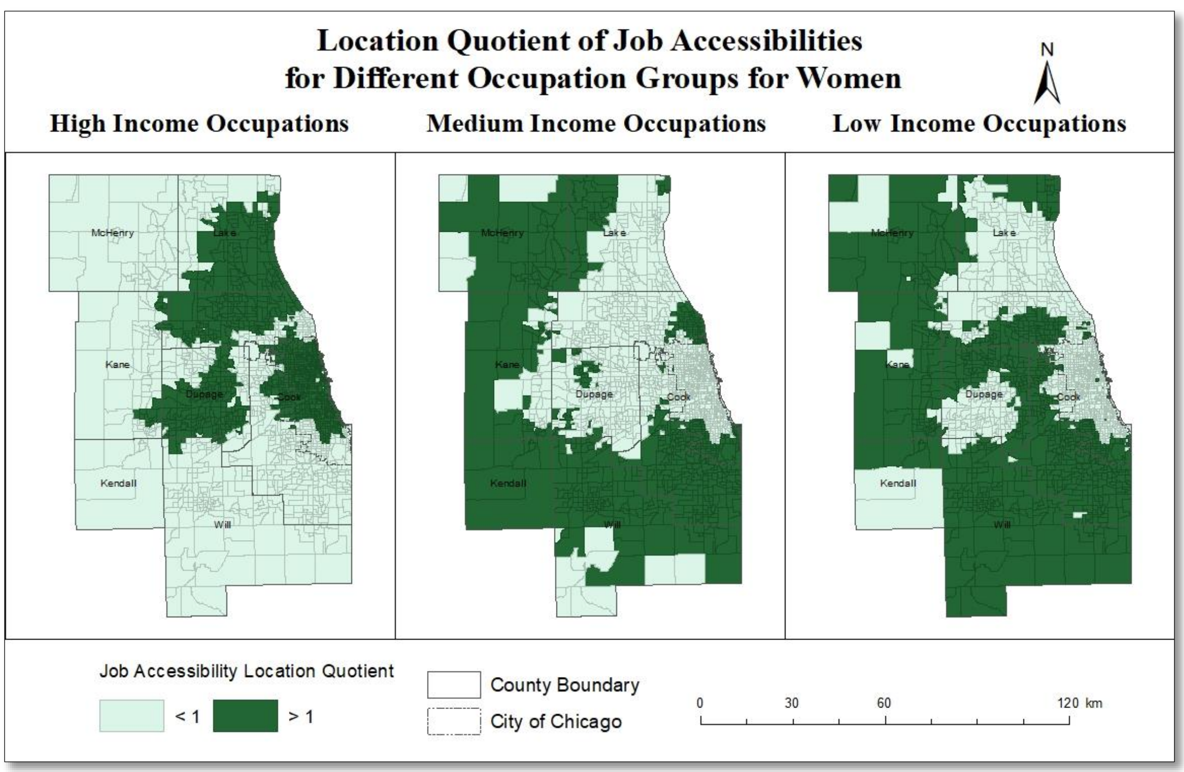


Figure 5.12. Spatial distribution of women's LQs for the three occupation groups

The results of men and women's LQ distributions for the three occupation groups are shown in Figure 5.11 and 5.12. All LQ values are either greater or lower than one. No census tract with a LQ value equivalent to one is found from the results. To help describe the LQ patterns more easily, LQ values larger than one will be denoted as high LQ values, and LQ values smaller than one will be denoted as low LQ values in the analysis below. The results indicate that the high-income occupations' high/low LQ values are distributed nearly in the opposite side from where the high/low LQ values for medium-income and low-income are distributed. According to the maps, the majority of locations which allow both men and women to access a greater share of high-income occupations than the regional average are distributed within or close to the CBD area. However, the high LQs for medium-income and low-income occupations are distributed in areas more distant from the CBD area than where the low LQs for these occupations are obtained.

The large variations in the spatial distribution patterns of LQ among the three occupation groups are connected with their different degrees of job compactness. The high-income occupations are more compactly distributed across the region, with a larger proportion of jobs concentrated in and around the CBD area than the medium-income and low-income occupations. Therefore, the residents living in or closer to the CBD area are able to access higher share of high-income occupations than the regional average. The more disperse distributions of medium-income and low-income jobs indicate smaller percentage of jobs distributed in the CBD and the surrounding area, but greater percentages in the remote suburb and the periphery. Therefore, the shares of medium-income and low-income jobs accessible by men and women are smaller than the average level in areas closer to the CBD, but are larger than regional average in suburbs and the edge.

Although women's high LQ values in high-income occupations are distributed at the same side of the region with men's, the spatial extent of women's high LQ values is much smaller than men's due to their shorter commuting time budget. Based on Figure 5.12, women's high-LQ areas are mainly consisted of three patches, including one covering the majority of City of Chicago, another covering a part of DuPage, and the third one enveloping both the north portion of Cook and the south portion of Lake. Unlike men's high-LQ areas for high-income occupations which have a more contiguous coverage, women's areas are spatially separate from each other. It can be explained by the reason that the job density of high-income occupation experiences subtle decrease first and then increase from CBD to DuPage and Lake. Women's more limited commuting time budget leads their accessibilities to be more sensitive to job density changes across locations. As a result, the distribution of LQs also demonstrates the first-decrease-then-increase patterns and hence form the patches. In addition, as aforementioned, the mean center of high-income occupations is located further north, which suggests a larger proportion of high-income jobs distributed in the north of the region than the other two occupations. The maps indicate that both men and women's high LQs for high-income occupations show northerly distributions. Due to the higher sensitivity of women's accessibilities to job density change, this trend is more obvious for women's high LQs distributions.

The high LQ areas for high-income occupations indicate where people can access a higher than regional average proportion of high-income jobs and hence give them a relatively better chance to land such a job. Women's significantly smaller high LQ areas for high-income jobs presents another evidence for women's disadvantageous status in competing high-income jobs with men, which contributes to women's lower presence level in high-income occupations.

5.5 Summary

This chapter carried out a case study in CMA to investigate the gender difference in accessing jobs using the methodology framework proposed in Chapter III. Two major purposes are served by the investigation. First, it is expected that real cities will have a more irregular urban form than those presented in the simulated models and can lead to more complex job accessibility patterns. The case study offers an opportunity to compare the job accessibility patterns in CMA with the patterns found from the simulated models, which can help us gain a more comprehensive understanding on how the more complex job distributions will influence the job accessibility patterns in the study area. Secondly, as detailed employment and occupation data is available for a real city, it becomes possible for the case study to investigate the variations of job accessibility for different occupation groups. Such an investigation is not included in the simulated models due to the lack of the corresponding data. The variations of job accessibility for different occupation groups are expected to provide insights on understanding the occupational gender segregation situation in CMA.

To accomplish the above purposes, the two factors that influence men and women's spatio-temporal job accessibilities were analyzed respectively first, with data extracted from ACS 2006-2010 and CTPP 2010. Evaluations on men and women's job accessibilities using the methodology framework proposed in Chapter III were then carried out for the CMA region. The following conclusions are drawn based on a series of analysis on the accessibility measurement results.

First, men and women's accessibility patterns for overall job opportunities generally match the accessibility patterns detected in the simulated monocentric patterns. On the one hand, the spatial distribution of accessibilities for both gender groups generally demonstrate monocentric characteristics. On the other hand, women have much lower job accessibilities than men regardless of where they live, and women's accessibilities vary significantly higher by locations than men's. These results demonstrate the feasibility of the simulated models in explaining the connection between urban form and gender differences in accessibility patterns. At the same time, due to the uneven distribution of the hierarchical road network, and the more complex urban form of CMA, more irregular accessibility patterns in CMA are captured from the analysis. These distinct accessibility patterns of CMA extend the analysis on the relationship between urban form and accessibility patterns of the models, and help broaden the understanding of the influence of job distributions on men and women's accessibility patterns.

Secondly, the analysis indicates the existence of occupational gender segregation in the study area, with women underrepresented in high-income occupations. Through comparing men and women's accessibility patterns among high-income, medium-income and low-income occupation groups, the research finds that women can only gain high accessibilities to high-income jobs in more limited locations, but low accessibilities in much larger space than men in both absolute and relative terms. This gendered pattern demonstrates women's disadvantageous status in competing for high-income jobs with men, which contributes to comprehending the unequal gender distributions in high-income occupations. In addition, the analysis also finds the more compact job distribution of high-income occupations than medium-income and low-income occupations, and confirms its contribution on enlarging the accessibility disparities between gender groups and leading to women's more disadvantageous status in accessing high-income jobs. Finally, the information on the locations that provide higher chance for women to access high-income occupation groups are offered, which will be useful for women who are struggling with restricted space-time accessibilities to high-income job opportunities to find the locations that can improve their accessibilities to these jobs.

CHAPTER VI

CONCLUSION

Gender occupational segregation remains a strong issue in today's society. While men are overrepresented in professional and higher-paid occupations, women remain highly concentrated in the traditional female-dominated, service-oriented, and lower-paying jobs. Various theories have been proposed to explain the reasons behind the occupational gender segregation issue, mainly from economic and social angles. However, spatial factors also play key roles in understanding people's employment patterns, since employment can be considered as the outcome of a pairing process of job opportunities and matching employees at different locations. Based on a time-geographic approach, this research identified the spatial and temporal constraints faced by men and women in accessing jobs and examined how these factors lead to different outcomes in employment opportunities between gender groups, which can further contribute to the gender occupational segregation issue. This chapter will summarize the major findings and contributions, followed by a discussion on some of the limitations of the research. The directions for future research will be discussed at the end of this chapter.

6.1 Findings and Contributions

The previous accessibility-related studies mainly focused on examining the restriction of gender roles on women's job accessibilities through the statistical relationship between indicators of gender roles and commuting lengths. However, they are not able to explicitly explain the mechanism of how gender roles constrain women's time and lead to their disadvantageous status in accessing jobs. In addition, the spatial distribution of jobs, the other factor which also imposes significant effect on men and women's job accessibility, cannot be fully incorporated in the commuting-based statistical analysis. The conventional place-based accessibility methods are able to capture the effect of job distribution patterns on accessibilities. However, the methods tend to focus on places only and do not consider the different time constraints encountered by men and women in the accessibility analysis. Based on a time-geographic approach, this research proposed a new methodological framework to study men and women's space-time accessibilities to employment opportunities in a metropolitan area. This framework aims at explaining the mechanism of how gender roles and the spatial distributions of jobs inseparably function and impose different levels of spatio-temporal constraints on men and women's employment activities, which leads to different job accessibility patterns between men and women.

Explicitly incorporating time constraints in the analysis, this research studied how job distributions can affect men and women's job accessibility patterns. Representing various job distribution patterns in monocentric and polycentric urban forms, a series of simulated city models were established to facilitate the investigations on the associations between urban forms and men and women's job accessibility patterns with the proposed time-geographic methodology framework. In addition to the scenario-based analyses, the methodology framework was also applied to the case study in CMA, for the purpose of not only gaining further understanding on how the more complex job distribution patterns in a real-world city will influence space-time accessibility to jobs, but also examining whether/how the gendered job accessibility patterns would contribute to the uneven distributions of men and women across occupations.

The results of the scenario-based analyses confirm several major findings from previous studies using the conventional methods, including women's overall disadvantage in accessing jobs that is indicated by the commuting-based statistical analysis, and the varying job accessibility patterns by locations in the metropolis which have been detected using the conventional place-based accessibility method. Furthermore, the proposed methodology framework is capable of capturing the joint influence of time and space constraints on men and women's job accessibilities. Such a capability allows for revealing the different accessibility patterns between gender groups, as well as providing explanations on the mechanism that leads to such patterns, both of which are unable to be accomplished by the previous research. In particular, the gender difference in accessing jobs detected in this research can be summarized as the following patterns.

First, while job accessibilities are unevenly distributed across space for both men and women, the accessibility variations among locations are significantly greater for women than men. Due to women's higher share of household responsibilities, they tend to have more limited commuting time budget, which leads to their accessibilities being more sensitive to the change of job densities across space than men. This gendered accessibility pattern has highlighted the more important role played by residential location in influencing women's accessibility than men. Changing locations will not largely alter men's accessibilities, but the experience of accessing jobs for women will be significantly different in varying areas of the region.

Secondly, the spatial distributions of men and women's job accessibilities demonstrate distinct patterns under different urban forms. Men and women in monocentric models both demonstrate monocentric characters, as the job accessibilities decline from the CBD to the city fringe. In addition, the associations between the degree of concentration and CBD size in monocentric models and job accessibilities are also similar for both gender groups. The increase in the degree of concentration and the shrinkage in CBD size will enhance the job accessibilities in CBD and its surrounding area but reduce the percentage of jobs men and women are able to access in the periphery. However, it is also detected that men can gain high job accessibilities in a much larger area than women in every monocentric model, which reinforces the findings of women's disadvantageous status in accessing jobs. For the polycentric models, the general accessibility distributions remain monocentric for men. The shift in the locations of subcenters and the amount of jobs distributed in each employment center will change the distributions of higher and lower accessibilities, but will not alter the general accessibility distribution patterns for men. However, depending on how the subcenters are spatially distributed in the city, women's general accessibility distribution can either demonstrate monocentric or polycentric patterns. When the employment centers are more closely distributed with each other, women's accessibility distributions remain monocentric, but the high accessibility areas where women can access all employment centers cover much more limited space than men's. When the centers are distributed further apart, women are not able to reach all the centers at any place in the city given their more limited time budget for traveling to work. Therefore, the general distributions of accessibilities for women then demonstrate polycentric patterns, and the high accessibilities areas are distributed at places in between the centers instead of clustered around the CBD area.

Thirdly, the gendered job accessibility distribution patterns lead to the uneven distribution of gender ratio in accessing jobs across the space, and the gender ratio distributions are also closely related with urban forms. A monocentric form where employment opportunities significantly concentrate in the CBD area offers the narrowest gender accessibility gap within and around the employment center but also results in extremely large gender disparities in the metropolis fringe. Meanwhile, in a metropolitan area with a more dispersed job distribution, such as a polycentric city, the gender ratio in accessing jobs is more evenly distributed across the space. While the gender equity in accessing jobs in the periphery is slightly enhanced, those living close to the employment centers experience reduced job accessibilities.

The above gendered patterns of job accessibilities not only illustrate women's lower accessibility than men, but also point out which parts of the metropolis offer women higher job accessibilities and more equal job opportunities with their male counterparts. The findings also reveal how the different urban forms change the locations and areas of women's higher accessibilities, and which urban form provides more equal job accessibilities to the residents. This information would help policy makers improve urban planning strategies to alleviate gender inequity issues in employment accessibilities.

In addition, the CMA case study suggests that the variations of job accessibility patterns for different occupation groups are able to provide insight on understanding the unequal gender distributions across occupations. A more compact spatial distribution of jobs for high-income occupations than medium-income and low-income occupations is detected for CMA. The different job distribution patterns among the occupation groups lead to women gaining high accessibilities in smaller areas but low accessibilities in much larger space than men. The finding of women's more disadvantageous status in competing for high-income jobs with men contributes to understanding the underrepresentation of women in high-income occupations. Besides, the information on the locations where women are able to gain higher chance to access high-income occupation groups in CMA is provided in the study, which will be helpful for women who are struggling with restricted space-time accessibilities to high-income job opportunities to make easier relocation decisions and obtain more equal job opportunities with their male counterparts to work in more professional occupations and receive higher earnings.

6.2 Limitations and Directions for Future Research

This research assumed the same travel capacity for all residents as each individual commutes by car, while other forms of transportation have not been taken into consideration when evaluating men and women's job accessibilities. The assumption reduced the complexity of accessibility results, which has helped efficiently identify the influence of urban form on gender difference in accessing jobs. However, there are a considerable number of workers highly relying on other transportation modes, especially public transportation, for commuting. Compared with automobiles, traveling by public transportation usually requires longer time, hence imposes a higher level of constraint on the spatial extent people can reach within their time budget. In addition, previous literature (e.g. Preston & McLafferty, 2016; Hu & Schneider, 2017; McLafferty & Preston, 2019) suggests a higher percentage of women commuting by public transit than men. Therefore, the absence of the other means of transportation in the investigation might have led to an underestimation of the gender disparity in accessing jobs.

Besides, the research mainly focused on how gender roles and job distribution patterns influence men and women's job accessibilities and eventually lead to the markedly different gender distribution across occupations. There are other factors that are also closely related with the gendered employment outcomes. For example, whether individuals' skill sets match the job requirements has a significant effect on the pairing process of people and jobs. In addition, one's personal work preference will also influence his/her job choices. Gaining the knowledge of job accessibilities for men and women with different skill sets and job preferences to their matched employment opportunities would help policy makers develop more targeted and efficient plans to improve the unequal gender distribution across occupations. However, since time and space are the only two factors that are included in the research, the job accessibilities for men and women with different job qualifications and preferences have not been revealed in this study.

Given the limitations discussed above, future work is needed to further refine the analysis and findings of this research. Besides automobiles, other modes of transportation, such as walking, cycling, and buses need to be included in the accessibility investigation. Several publicly available tools provide transportation-associated information at fine geography scales by genders, such as CTPP, Longitudinal Employer-Household Dynamics, and National Household Travel Survey. From these tools, means of transportation data can be extracted and the spatio-temporal accessibility to jobs can be evaluated to more accurately depicting the gender differences in accessing jobs. More efforts can be endeavored to incorporate the other factors that also determine men and women's employment outcomes. Population attributes such as educational background and work experience can be collected, based on which men and women can be further classified into groups. Job accessibilities for each population group to the matched occupations can be evaluated to help policy makers develop more efficient urban planning strategies to combat gender occupational segregation in the society.

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VITA

Qinyue Pan

Candidate for the Degree of

Doctor of Philosophy

Dissertation: A TIME-GEOGRAPHIC APPROACH TO INVESTIGATING GENDER DIFFERENCE IN ACCESSING EMPLOYMENT OPPORTUNITIES IN A METROPOLITAN AREA

Major Field: Geography

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Geography at Oklahoma State University, Stillwater, Oklahoma in May, 2021.

Completed the requirements for the Master of Science in Geography at University of Alabama, Tuscaloosa, Alabama in 2011.

Completed the requirements for the Master of Science in Geography at East China Normal University, Shanghai, China in 2009.

Completed the requirements for the Bachelor of Science in Geography at Suzhou University of Science and Technology, Suzhou, China in 2006.